The Southland Economic Project

AGRICULTURE AND FORESTRY

beef+lamb new zealand

environment SOUTHLAND REGIONAL COUNCIL Te Taiao Tonga

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Deer Industry New Zealand

FAR

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Cover photo: Rolling hills near Hedgehope, Southland
Source: Matt Couldrey

The Southland Economic Project:

Agriculture and Forestry

Technical Report

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The Southland Economic Project

This report has been produced for **The Southland Economic Project**. The aim of this project is to create ways of understanding the possible socio-economic impacts of achieving 'limits' for water in Southland under the National Policy Statement for Freshwater Management (2017).

The Project is a joint venture between DairyNZ, Beef + Lamb New Zealand Ltd., Department of Conservation, Ministry for Primary Industries, Ministry for the Environment, Southland Chamber of Commerce, Te Ao Marama, and Environment Southland.

It also closely involves Deer Industry New Zealand and New Zealand Deer Farmers Association (Southland Branch), the three territorial authorities in Southland (Invercargill City Council, Southland District Council and Gore District Council). As well, the Project has had support from Foundation for Arable Research, and Horticulture New Zealand, and forestry companies: Southwood and Rayonier.

The Project is undertaking three major studies that flow on from each other:

Study1: Economic Sectors:

A. Agriculture and Forestry
B. Urban and Industry

Study 2: The Southland Economy (The Southland Economic Model)

Study 3: Community Outcomes

This report is an output from the Agriculture and Forestry component of Study 1. The report and its related datasets are being used in the development of The Southland Economic Model for Fresh Water within Study 2. Study 3 uses information from The Southland Economic Model for Fresh Water to understand connections between the economy and local communities across the region.

Preface

This report brings together research undertaken by industry groups for **The Southland Economic Project**. The research is presented in **Part C** and its context is described in **Parts A and B**. Additional information giving more detail on some aspects of this report is contained in the appendices. Individual sections of this report are written by different authors as identified below. Environment Southland staff contributed to many of these sections and wrote all other sections.

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Acknowledgements

As with everything to do with water quality, understanding the relationship between farm nutrient loss and profitability is a complex task. The surveying, modelling, and analysis of each of the 95 case study farms has taken roughly two weeks dedicated effort, and each one captures detailed information about a farmer's business. To complete this research, all of the organisations involved have made a considerable investment in the future of the agricultural sector in Southland. In the first instance, the research would not have been possible without the support of the farmers and local experts who gave their precious time, information and advice. It also benefitted from the knowledge and experience of a large number of industry representatives.

Numerous people provided invaluable help and patience over many months during the process of taking the research and turning it into this report. Of note are John Somerville (New Zealand Deer Farmers Association – Southland Branch), Darran Austin (MPI), Ken Murray (DOC), Jenny McGimpsey (B+LNZ), Jan Riddell (ex-Environment Southland Councillor), Denise McKay, Fleur Matthews, Felicity Durand, Carmen Russell, Fiona Young, Gary Morgan (all from Environment Southland), Simon Moran and Russell Cannan – some of whom made contributions and others waded through more than one draft version. Thanks are also due to the reviewers: Raymond Ford (Environment Canterbury), Blair Keenan (Waikato Regional Council), and Matthew McCallum-Clark (Incite).

All of these people and organisations have made this commitment to make sure that information and understanding on the possible economic impacts is readily available as Southland enters into setting limits for fresh water.

Image 1: Ōreti River
Source: Rebecca Whyte

Acronyms and Abbreviations

B+LNZ Beef + Lamb New Zealand Ltd

DINZ Deer Industry New Zealand

EBIT Earnings Before Interest and Taxes

EBITR Earnings Before Interest, Taxes & Rent

Eff.ha Effective hectare

FAR Foundation for Arable Research

FMU Freshwater Management Unit

FPBT Farm Profit Before Tax

HortNZ Horticulture New Zealand

LUC Class Land Use Capability Class

MPI Ministry for Primary Industries

MFE Ministry for the Environment

N Nitrogen

OP Operating Profit

P Phosphorus

RPR Reactive Phosphate Rock

SU Stock Unit

Image 2: Limestone cliffs and sunflower crop at Clifden
Source: Emma Moran

Executive Summary

Water, and the land it flows through, has a natural capacity to process (or attenuate) nutrients and other substances. When by-products from economic activity end up in water this natural capacity is 'used' or taken up. They add to the concentrations and loads (or total amounts) of substances in the environment and can cause water quality issues.

Many new initiatives are being introduced that are designed to improve how people use water - in this context, the 'use' of water is in its broadest sense, both as a water take and to receive by-products. At the centre of these efforts is the National Policy Statement for Freshwater Management (2017), which requires environmental 'limits' to be set for water quality and water quantity, where a limit is the maximum amount of water available to be used.

As part of implementing the National Policy Statement for Freshwater Management (2017), Southland has been divided into five freshwater management units (FMUs) based around the region's geography, and particularly its large river catchments: *Fiordland and Islands*, *Waiau*, *Aparima*, *Ōreti* and *Matāura*. Community processes to set limits in these FMUs are planned as part of the **People, Water and Land Programme**. Limits may require people to change the way they use water, particularly to receive substances like nutrients, which is likely to have socio-economic impacts during the period of transition. **The Southland Economic Project** was set up to develop ways of understanding these impacts so that good information will be available during these community processes.

This report brings together a large amount of research on the agriculture sector that industry groups have done as part of **The Southland Economic Project**. Agriculture occupies 87 percent of the developed land in Southland, and the aim of this research was to develop information on the effectiveness and impacts on profitability of managing nutrient losses within farm production systems. Mitigations for sediment and microbes were not included because of difficulties in estimating their losses at a farm-scale. It was the first time all of these industry groups have collectively been involved in research of this type, and it was also the first time that such research has been done for farms across a region. Local councils have contributed to similar research on town wastewater schemes across Southland that is the subject of a second report: *The Southland Economic Project: Urban and Industry*.

Similar information was not developed for the forestry sector, even though it makes up almost ten percent of the developed land, because this sector generally has relatively low nutrient losses in Southland. At the time, it was assumed that the effects of forestry on water bodies were to be managed under the proposed National Environment Standard for Plantation Forestry (2015).

This report highlights Southland's reliance on agriculture, compared to other regions, and it develops a number of themes. One is the role of Southland's environment in the development of agriculture and forestry and, in turn, how this development has modified the environment over the years. Southland's water and land is highly connected, in comparison to many other regions. Water now flows more rapidly through the landscape than in the past, and there are fewer opportunities for the natural processing of nutrients carried in it. Other themes are the complexity and diversity within agriculture, and the connections (and integration) between its different industries, both on-farm and between farms, which were all important considerations in this research.

Methodology

To develop information for the agriculture sector, the industry groups surveyed a total of 95 farms across Southland: 46 drystock farms, 41 dairy farms[1], 4 arable farms, and 4 horticultural growers. This information was used as a set of farm case studies that explored:

1. A farm's estimated nitrogen and phosphorus losses and profitability; and
2. The effectiveness of mitigation measures (or actions) to manage nutrient losses and their impacts on farm profitability.

The farm case studies were created using a two stage modelling process. In the first stage, two baseline files were developed for each farm using two computer software programmes that estimated existing nutrient losses and profitability. In the second stage, the input data for each farm's nutrient budget and financial files were altered to simulate a range of on-farm mitigations scenarios. The two software programmes used in this process were OVERSEER® nutrient budget model (Version 6.2.1) for all 95 farms, FARMAX® for the operating profit of 87 pastoral farms, and Microsoft Excel® for the gross margins of the eight arable farms and horticultural growers. Each industry group tailored this basic methodology to accurately reflect the nature of its industry and production systems.

OVERSEER® was designed for testing the relative effects of possible changes in farm management on nutrient losses from a farm, which is how it was used in this research. The mitigation modelling focused on those able to be represented in OVERSEER® out of a wider set of possible mitigations. In general, the financial measures of profitability used in this research were all before interest and tax payments. The measure used for the drystock farms was also before any payments for rent. The report also identifies two important measures for assessing policy impacts: an industry's land area and its number of farmers.

The farm case studies are a key input into **The Southland Economic Model for Fresh Water**, which is a regional model of Southland's economy being developed within **The Southland Economic Project**. The Southland Economic Model will trace possible transitions pathways (or routes) as the economy evolves over time. It will be used to test the economic impacts of "what if" policy scenarios for achieving limits in each FMU. Additional work is being done on how the economy currently influences community outcomes in Southland to give some understanding of possible social impacts of policy.

Baseline Results

The baseline nutrient losses show each farm's estimated start point for the mitigation scenarios. Factors driving baseline losses include land use, farm management and environmental conditions (climate, topography and soils). As case studies, a large number of diverse farms were included in this research and they covered a large land area. Each farm had its own set of circumstances and the production systems were specific. Three sheep and beef farms were so complex they were unable to be represented realistically in OVERSEER®.

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[1] One farm was a composite farm based on real farm data.

These results indicate each industry's range of nutrient losses but not necessarily its distribution (i.e. how they fall within the range). Horticultural crops were represented as three case studies within a sheep farm, reflecting how they occur in Southland and the rotational nature of the crops over time. Figure 1 shows the baseline nitrogen losses for 90 case study farms, (three sheep and beef farms, one horticulture, and one arable property were unable to produce baseline results) and Figure 2 shows the baseline phosphorus losses for 87 case study farms across the industries, (in addition to the five unmodelled farms, the horticulture case studies did not report phosphorus losses).

The baseline results show that within an industry, there was no clear relationship between a farm's baseline nitrogen or phosphorus losses and its profitability. In other words, farms with lower nutrient losses were just as likely to be profitable as farms with higher nutrient losses. For example, the two most profitable dairy farms had reasonably low nutrient losses, the third farm had nutrient losses that were average for the 41 dairy farms, and the fourth most profitable dairy farm had relatively high losses. The results for the most profitable sheep, beef and deer farms tell a similar story.

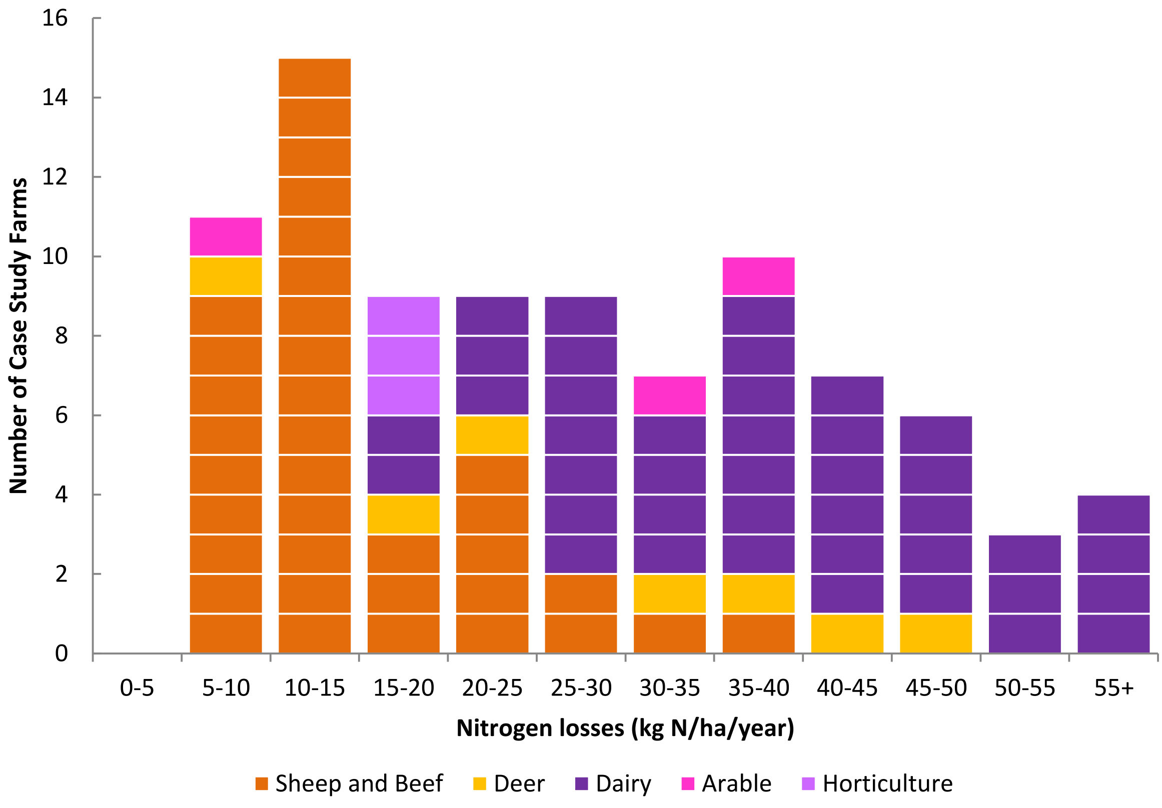

Figure 1: Baseline nitrogen losses for Southland case study farms

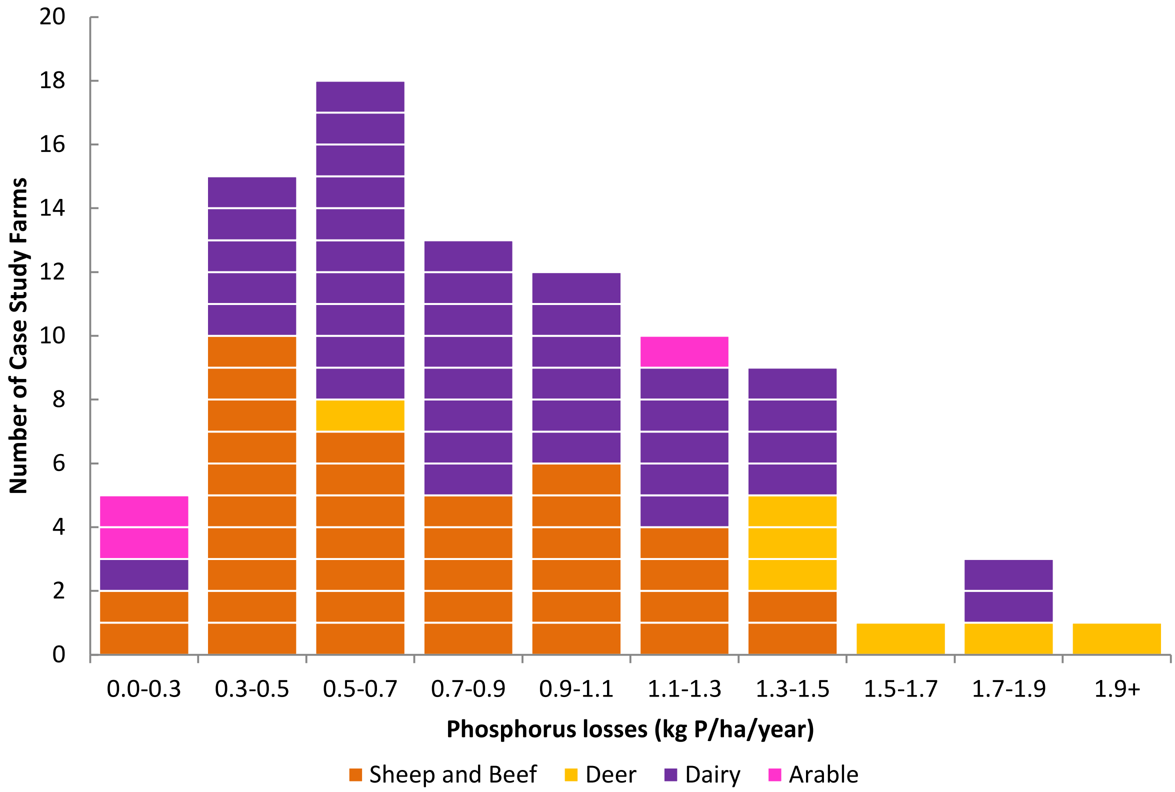

Figure 2: Baseline phosphorus losses for Southland case study farms

Mitigation modelling

Each industry used its farm baseline files as the starting point to model a set of industry specific mitigations. For the sheep and beef, deer, and arable farms, individual mitigations were used for nitrogen and phosphorus losses. For horticulture, individual mitigations were used for nitrogen losses only. For the dairy farms, combinations of mitigations were used to achieve percentage reduction targets in nutrient losses (e.g. from -10% to -40%) within the existing farm production system (low input, medium input or high input). The results of this modelling show estimates of the effectiveness and impacts on profitability of different mitigation options in OVERSEER®, and are a reasonable indication of what can occur on-farm. There are many other mitigations that are relevant, they were just not able to be represented using the existing model versions. These results are summarised in each industry's section in Part C of this report.

Key Findings

Based on the mitigations modelled, the key findings were:

1. The mitigations usually reduced losses of one or both nutrients (by lesser or greater amounts) but also reduced profitability for most farms. The main reason that managing nutrient losses reduces profitability is it changes the farm production system. While many farms have started adjusting their production systems to manage nutrient losses, they will need to continue managing their nutrient losses in the future, while maintaining profitability.
2. Some farms had less capacity to reduce nutrient losses than others in the OVERSEER® analysis. The main reasons were:
    a. those farms had low nutrient losses to start with (so the mitigation options had little effect);
    b. the impacts of the mitigation options on profitability were high;
    c. the mitigation options were not applicable to a farm; and/or
    d. the mitigation options were not sufficient to manage the farm's nutrient losses (given its soils and topography).
3. The effectiveness of specific mitigations varied by industry and nutrient. For example, reducing stocking rates was not well suited to drystock because stocking rates were generally within the carrying capacity of the land. On deer farms, managing fence pacing and wallowing was an effective mitigation for phosphorus losses but had limited success in reducing nitrogen losses.
4. Within most industries, the farms with higher baseline nutrient losses tended to have more mitigation options, and these mitigations were usually more effective, than the farms with lower baseline nutrient losses. This finding was not the case for the dairy industry. Some dairy farms had relatively high baseline nutrient losses for the industry and few mitigations. For these farms to achieve relatively low nutrient losses, they will need to consider other options, such as retiring land or a change in farm production system.
5. The impacts on profitability of particular mitigations often varied by farm and industry. For example, in pastoral farming the mitigations that had the least impact often related to fertiliser use (timing and application rates), but similar mitigations had a considerable impact for cropping activities because of the close relationship between fertiliser and crop yields (quantity) and quality. If fertiliser rates and applications do not meet a crop's requirements then growers are unlikely to grow a particular crop.

Main Limitations

This research's main limitations are the effort required to survey and model a range of farm types, and the flexibility of any software programme in representing the diversity of farms and mitigations.

The effort required to survey and model an individual farm meant that it was not practical to cover the full diversity and complexity of farming across Southland. The 95 farms is a comprehensive set but they are not fully representative of each industry. The sample size, and the process of working with industry, provides a good level of robustness and the use of this information will improve understanding. The need to use software programmes for this research meant that it was not possible to represent aspects of some farms and some mitigations. To a certain extent this limitation is unavoidable because no model can perfectly reflect reality. The software programmes used in this research are continually being advanced and some of the challenges faced in this research have since been resolved in subsequent versions, while others are under development.

This research in Part C of this report was done to create a farm dataset for the Southland Economic Model for Fresh Water. As it stands, the dataset is a snapshot of a number of different farms in the 2013-14 year and estimates the effect and impacts of a range of mitigation scenarios. It does not consider how farmers will need to adapt over time, including policy implementation rates and mitigation adoption rates – these factors will be included when the dataset is used in the Southland Economic Model. It also does not reflect any technological change and new opportunities that will arise as Southland transitions towards achieving the requirements of the National Policy Statement for Freshwater Management (2017). Consequently, a great deal of care needs to be taking when interpreting the research, and specific results should only be considered within the context given in Parts A and B of the report.

Image 3: Forage crop near Morton Mains, Ōreti FMU
Source: Simon Moran

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Introduction

In response to declining water quality in many places in New Zealand, government and non-government organisations are introducing a range of initiatives that are designed to improve how people 'use' water. In this context, the use of water is in its broadest sense – from situations where water is taken from a water body (e.g. a lake, river, stream, or aquifer) to circumstances where waste substances, such as surplus nutrients and sediment, end up in water body.

These initiatives are both non-regulatory (e.g. milk companies' conditions of supply) and regulatory (e.g. policies and rules in regional plans), and they are generally aimed at changing people's behaviour. At the centre is the Government's **National Policy Statement for Freshwater Management** (MfE, 2017). It requires , among other things, 'limits' to be set on the total amount of fresh water that can be used – once enough has been put aside to make sure that things like ecosystem health and human health are safeguarded. These limits will be set for water quality and water quantity.

For water quality, limits relate to the environment's capacity to process (or 'attenuate') waste from human activity. When this capacity is reached, additional substances can overwhelm a system, creating pollution and contributing to water quality issues, such as algal growth and poor water clarity. To address these issues, environmental limits on the use of fresh water will be set for either part, or all, of a water body based on loads (a total amount over a specific time period – daily, monthly, annually) and concentrations (a rate, or amount within a specific volume) of particular substances. Loads are particularly relevant where a catchment contains a water body, such as a lake or an estuary, which acts as a sink for waste substances.

Although awareness of water quality issues has improved over recent years, the economy's use of fresh water (both for water takes and to receive by-products as waste) continues to increase in Southland and elsewhere in New Zealand. One reason is that standard assessments of productivity do not usually include an economic activity's use of natural resources over the longer term. In other words, they are partial assessments of productivity, and do not necessarily reflect sustainability. Where an activity's use of water is not accounted for, and it impacts on other values, then all of the community is, in effect, subsidising that activity. This is the case regardless of the economic sector being considered (e.g. agriculture, forestry, manufacturing, tourism or local government).

Regional councils, including Environment Southland, are required to implement The National Policy Statement for Freshwater Management in their region, which includes setting limits for fresh water within Freshwater Management Units (or FMUs). In Southland there are five FMUs[2], based around its large river catchments, and four main substances creating water quality issues: surplus nutrients (nitrogen and phosphorus), sediment and microbes (for which *Escherichia coli* is used as an indicator). These substances are by-products from both rural and urban activities. They flow in water across, down or through the surrounding land, and accumulate in the region's rivers, lakes, groundwater, wetlands and estuaries.

[2] Southland's FMUs are described in Part A of this report.

Farming is a balancing act between inputs and outputs to produce food efficiently and profitably, and fresh water is a vital component across the whole farm production system. Farmers use water as an input in production, for things like stock drinking and irrigation. Water also takes away substances (e.g. nutrients, sediment and microbes) that are created alongside outputs, such as meat, crops, and milk. It is less obvious than on the input-side of the production system, but nutrient losses are a 'use' of water and can contribute to declining water quality. Although most farm production systems were not set up on the basis of having to account for nutrient losses, many farmers now adopt good management practices (e.g. rates and timing of fertiliser applications, alternative harvest techniques, and riparian fencing) to manage their nutrient losses.

These good management practices are one type of a wider set of actions or 'mitigations' available for managing a farm's nutrient losses. Fewer farmers go beyond this point because using these mitigations usually impacts on farm profitability. As a result, operating in ways that create nutrient losses has a value (in the short-term) to farmers and all others in their value chains, including people who are the final consumers of their products in both domestic and export markets. Despite this wider value, farmers generally have to absorb changes in profitability because they compete in export markets and have little ability to influence prices for their products. Understanding the relationship between managing nutrient losses and farm profitability is at the heart of this research.

In Southland, community processes to set 'limits' are planned within the **People, Water and Land Programme**[3]. Future policy options to achieve these limits may mean people in these communities need to change the way they use water, particularly for receiving waste such as surplus nutrients. Changing people's use of water is likely to have impacts as they go through a period of transition. **The Southland Economic Project** was set up to develop robust ways of understanding these possible impacts so that relevant information will be available during limit-setting. This report brings together research that industry groups have done within **The Southland Economic Project** specifically for the agricultural sector.

The purpose of this research was to develop information on better managing farm nutrient losses within current production systems. Specifically, it focused on 95 case study farms across Southland and investigated:

1. The current performance of farm production systems in terms of profitability and nutrient losses; and
2. The effectiveness of on-farm mitigation measures in managing a production system's nutrient losses and their impacts on a farm's profitability.

The methodology and results of this research are summarised in **Part C** of this report. In completing this research, the organisations involved have created a comprehensive source of information about agriculture for Southland. The report also gives an overview of the forestry sector in Southland and explains why similar research was not completed for this sector at this stage.

[3] People, Water and Land is a partnership programme between Environment Southland and Te Ao Marama Incorporated, who represent tangata whenua interests in resource management and other aspects related to local government for iwi in Murihiku/Southland. People, Water and Land has superseded Water and Land 2020 & Beyond.

This research focused on losses of nutrients (nitrogen and phosphorus), not because these are the only waste substances creating water quality issues in Southland, but because there are limited models available to estimate losses of microbes and sediment at a farm-scale. Some of the mitigations for phosphorus losses are similar to those that are used to manage suspended sediment.

In general, nutrient losses from farms are controlled by specific factors: land use, farm management, and environmental conditions (particularly climate, soils and topography). These factors shaped the general approach to the research methodology and determine the underlying assumptions in the OVERSEER® Nutrient Budget Model (referred to as OVERSEER for the remainder of the report), which is used to estimate nutrient losses in **Part C**. **Part A** outlines general information on Southland, including climate, soils and topography. **Part B** describes Southland's agricultural and forestry sectors, including the influence of environmental conditions and information on land use and farm management.

The wide variation in environmental conditions across Southland is one of the reasons each farm was considered as a separate case study. This variation also means that reducing the waste substances lost from the same type of farming or forestry activity will take more effort (or an increased level of mitigation) in some places than others. To some extent it comes down to location. One theme that runs through this report is the role of Southland's climate, topography and soils in nutrient losses. Other themes include the diversity in agriculture across Southland, and the connections between the different industries within the sector.

Parts A, B and C are designed to be read together, with **Parts A and B** providing essential context for understanding and interpreting the research in **Part C**. Accounting for nutrient losses within farm production systems is a complex topic and the report captures a lot of relevant knowledge. The report does not describe water quality issues across Southland – because these issues are well documented in a series of technical reports (Environment Southland, 2000; Environment Southland; Te Ao Marama Inc, 2011; Moreau & Hodson, 2015).

The results of this research give the best estimates of nutrient mitigation in models at present, given existing farming technologies, but are not necessarily what may occur on the ground in the future. What eventually occurs will depend on how people respond to change (which is always difficult to predict), how much they are asked to do, how much time they have, and the tools they then have to do it. Time is likely to improve people's ability to reduce nutrient losses but it may also increase the amount of nutrients that need to be reduced (i.e. the scale of the task).

"*As agriculture intensifies we are asking the environment to do more*"

Leon Black – Ermedale sheep farmer (pers. comm., March 2016)

This report, *The Southland Economic Project: Agriculture and Forestry* is the first of two reports. A second report, *The Southland Economic Project: Urban and Industry*, presenting research done for town wastewater schemes across Southland was produced in 2018. The datasets from all of this research is being used in **The Southland Economic Model for Fresh Water** (which is under development and due to be completed by the end of 2017). The model and the two reports will be used in the community processes to set limits on the use of fresh water in Southland. Section 6 in Part C (at the end of this report) briefly describes the model and how it is likely to be used in the future.

Report Structure

The next section explains why the research in this report focuses on the agricultural sector, and in particular pastoral farming. Following this section, the report is divided into three major parts:

Part A – Southland outlines background information on Southland and helps explain how the environment has both shaped, and parts of it have been modified by, agriculture and forestry. It covers: a general description of the land, water and people (including the economy); the 'Freshwater Management Units'; and relevant information about the climate and soils.

Part B – Agriculture and Forestry gives an overview of agriculture and forestry in Southland, building on the information in **Part A** (particularly around climate and soils), and giving wider context to the research methodology and results in **Part C**. It covers: each sector's geographical extent, farming characteristics, and land cover; a description of each main agricultural industry; and a description of the forestry sector.

Part C – Farm Case Studies summarises the research methodology for the agricultural sector and the results of this research. It covers: the general approach to the farm selection, survey and modelling, and mitigation scenarios for the agriculture sector; each industry's individual methods and summarise their results; and how this research is being used in **The Southland Economic Model for Fresh Water.**

Research Focus – Agriculture

Between 2014 and 2016, industry groups from across the agricultural sector surveyed and modelled farms in Southland to develop 95 case study farms. Of these 95 case study farms, 87 farms were pastoral – 41 dairy farms and 46 drystock (sheep, beef and/or deer) farms – and the remaining eight farms were arable or horticultural. This section explains why the research focused on the agricultural sector, and pastoral farming in particular. It also explains the different set of circumstances facing the forestry sector. The methodology and results for the 95 case study farms are presented in **Part C** of this report.

At a broad scale, the use of water to attenuate nutrient losses depends on the nutrient loss rates from particular land use activities and the total area of land over which they occur. Consequently, those land uses that have higher rates of loss and/or cover larger land areas are those that have the greatest water use and, consequently, are more likely to be affected by change in policy to achieve limits. These were the two main factors that determined the research focus in this report.

Overall, there is 1.2 million hectares of developed land in Southland. Agriculture covers over 1.04 million hectares (86.7% of the developed land). This sector includes a range of different industries, from drystock (sheep, beef and deer) and dairy (almost entirely cattle) through to arable and horticulture, but it has always been predominantly pastoral farming. There is considerable variation between these industries in both total land areas and rates of nutrient loss. Forestry (commercial, indigenous and farm forestry) covers 118,000 hectares (9.9% of the developed land). Forestry covers commercial plantation forestry (radiata pine, Douglas fir and eucalypts) and, to a lesser extent, farm forestry (tree blocks on-farm) and indigenous forestry (native timber harvest). Forestry has generally relatively low rates of nutrient loss (i.e. kg/ha/year), in comparison to agriculture, although the rates are variable during the rotation. The remaining 3.3 percent of developed land is used for all other activities, such as urban centres, transport networks, and manufacturing or processing industries.

The Agricultural Sector

This research focused on agriculture because of the large amount of developed land the sector covers across the region and its higher nutrient losses, in comparison to forestry. Agriculture began in Southland with European settlement, which followed the sale of the Murihiku Block from Ngāi Tahu to the Crown in 1852 (Grant, Updated 2015a). As the sector developed and intensified over time it has increasingly put pressure on the environment's natural capacity to attenuate surplus nutrients (i.e. those that are not used within a production system and lost as waste products).

Pastoral Farming

Although land use has changed over time, pastoral farming has always dominated agriculture in Southland. In the early days, farms were truly mixed production systems, including drystock, dairy and arable enterprises, but over recent years there has been a shift to focus on pastoral farming. In 2015, just over 99 percent of farms in the region were pastoral: either drystock or dairy. Originally, drystock farming meant sheep and beef, but in the 1970s the term widened with the emergence of the deer industry. Drystock farms usually have a mix of stock types and can include other enterprises such as arable cropping and dairy support. The number of dairy farms in the region has fluctuated over the years until the early 1990s when they expanded rapidly. The dairy expansion has created new opportunities for dairy support. There are examples of sheep dairy farming developing in Southland, but it is still on a small scale.

One way to indicate possible nutrient losses from pastoral industries at a broad scale is through stock units[4]. In general, total stock units in Southland have been increasing over time, first through land development and then from 1950 through intensification (Figure 3)[5]. Total stock units in the region grew steeply between 1950 and the mid-1980s as the grasslands revolution gained momentum across New Zealand. In Southland, the growth in stock units during this period was largely driven by sheep numbers and, to a lesser extent, beef cattle. The increase in stock units was because of a number of factors, including government subsidies, better feed, and the availability of technologies such as aerial topdressing. Beef stock units peaked around 1975, then declined up until 1985, and from then on have remained relatively constant. Sheep stock units peaked in 1986 and have been generally declining since. After 1985 there has been a clear shift from sheep to dairy, with the decline in sheep stock units being mirrored by an increase in dairy stock units. The development of the deer industry through the 1980s is also evident in the graph.

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[4] The stock unit conversion relates the energy requirements of various classes of stock to the requirements of one breeding ewe producing one lamb per year. One stock unit equals one breeding ewe that weighs 55 kg and bears one lamb. The amount of feed consumed by this ewe over a year is around 550 kilograms dry matter (it includes the feed consumed by her lamb up to weaning, at 3.5 months) (Fleming, 2003).

[5] Detailed information on stock units in Southland is available in Ledgard, G. (2013) *Land use change in the Southland region: technical report*. Environment Southland: Invercargill, New Zealand.

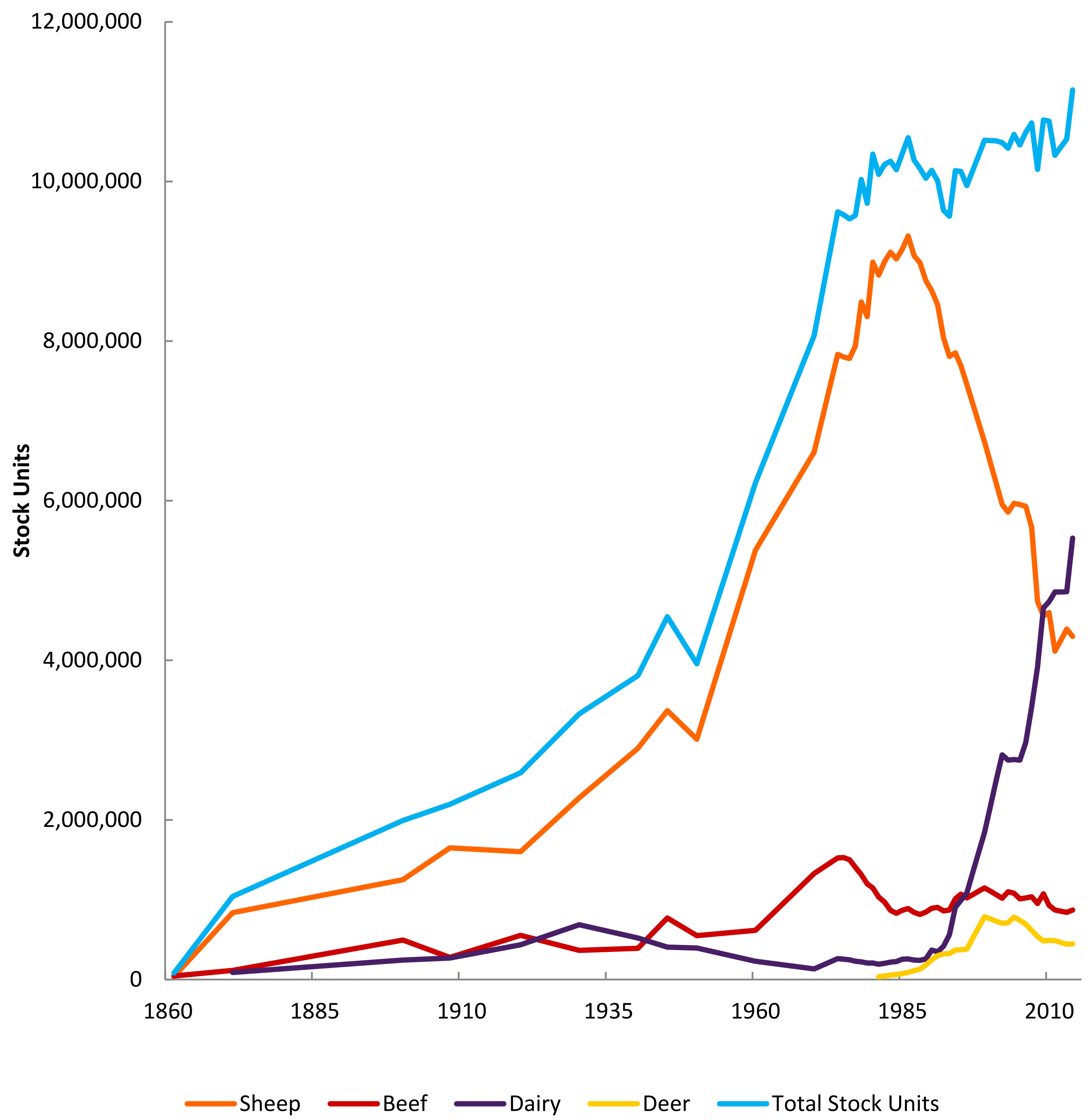

Figure 3: Stock units in Southland by stock type 1860-2014
Source: Ledgard (2013)

Since the mid-1980s, there has been a marked slow-down in the growth of total stock units in the region by comparison to the post-war years. From 1985 to 1993 there was a period of decline, following de-regulation of the New Zealand economy, which included structural changes to agriculture (particularly the removal of subsidies). However, between 1993 and 2014 total stock units in Southland increased from roughly 9.5 million to over 11.1 million. This overall increase of around 1.6 million stock units since 1993 tends to be masked by the sheer scale of the numbers involved (in the millions) and fluctuations of up to 600,000 stock units (around 0.4%) a year. During this time period agricultural land in the region also decreased by roughly 100,000 hectares as largely marginal land was transferred to the conservation estate through tenure review of Crown pastoral lease or it reverted back to indigenous cover.

The more recent increase in total stock units (from 1993) was caused by the expansion in the dairy industry. By 2010 dairy cattle stock units had surpassed sheep stock units in Southland and in 2014, there were 5.5 million dairy compared to 4.3 million sheep stock units. The distribution of case study farms in this research was chosen to roughly reflect the total stock units of the different pastoral industries in Southland. Of the 87 pastoral case study farms, 41 case study farms are dairy, 39 case study farms are sheep and beef, and 7 are deer (either mixed drystock or specialist deer). Some of the drystock farms included dairy support activities.

Arable Farming and Horticulture

The agricultural sector in Southland includes a range of cropping industries. Arable farming is the largest by land area and covers a total of 23,000 hectares. It developed early in the region with the growing of cereal crops, particularly milling wheat, for food production and, up until the 1980s, was second only to Canterbury as an arable region. Arable farming centres on the growing of cereals for stock feed and oats for both rolled oats and oat milk. Although its land area in Southland is far less than the pastoral industries, arable farming has strong connections with both drystock and dairy farming and many of these farms grow arable crops. The research included four arable case study farms that cover a broad range of grain and seed crops, forage crops, and stock types.

Horticulture in Southland is relatively more recent than arable farming and covers a total of around 700 hectares. It focuses on two main growers of root vegetables (mostly potatoes, carrots and parsnips). There is also small-scale production of perennial berry crops like blueberries and blackcurrants. Tulip bulb growing started up in the region in the 1950s with the arrival of Dutch immigrants and mostly revolves around the growing of tulip bulbs. This research included four horticulture case study farms: the two growers of root vegetables and two tulip bulb growers.

The Forestry Sector

The previous section explained why the research focus is on Southland's agricultural sector, and in particular pastoral farming. When this research was in its planning phase, MPI and plantation forestry representatives assessed the possible implications of 'limits' for fresh water in Southland on the forestry sector. It was decided that the sector was facing a different set of circumstances to agriculture in Southland and modelling for forestry was not as relevant. This section briefly outlines the reasons for this decision. More detail on the forestry sector is presented in Part B - Section 7.

Forestry covers 9.9 percent of Southland's developed land (compared to agriculture's 86.7%). In Southland, the forestry sector is dominated by commercial plantation forestry but also includes indigenous forestry and farm forestry. Plantation forestry equates to around 81,000 hectares; indigenous forestry, around 12,000 hectares; and farm forestry, 25,000 hectares. Commercial plantation forestry in the region is made up of large tracts of radiata pine and Douglas fir and eucalypts. The main indigenous forestry species is silver beech with some rimu and totara.

Although forestry uses water in its production systems both as an input (via rainfall) and to attenuate its waste by-products, the modelling of nutrient losses was not done for the forestry sector for the following two reasons:

1. Forestry's nutrient losses (over a full harvest period) are likely to be relatively low when compared to the agricultural sector, which makes it difficult to model mitigations and show any change as a result; and
2. The mitigations for forestry that are relevant in Southland are likely to be already required under the proposed National Environmental Standard for Plantation Forestry and not as a result of 'limits' for fresh water.

These reasons are explained in more detail below, but in essence they meant there was less need to investigate losses of nutrients or their mitigation for the forestry sector at the time this research was undertaken.

Nutrient Loss

In forestry operations the extent of nutrient losses depends on harvesting techniques, fertiliser applications, and silvicultural practices (e.g. weed control, pruning, thinning) (Payn & Clinton, 2005). In general, water quality issues concerning the forestry sector are usually linked to sediment losses (including erosion from land slips) and, to a lesser extent, nutrient losses. However, by comparison with the agricultural sector, forestry requires less nutrient inputs in terms of fertiliser[6] and usually has less effect on groundwater and surface water from nutrient leaching (Payn & Clinton, 2005). Although there is some evidence of higher losses in other regions, existing knowledge suggests the estimated nutrient losses for plantation forestry in Southland are 2 kg N/ha/year[7] and 0.2 kg P/ha/year (Ledgard G. , 2014). At this level, there are limited mitigation options available for reducing the nitrogen loss further.

When the trees are harvested, there are relatively more mitigation options for reducing phosphorus and sediment losses (compared with the rest of the production cycle). Different harvest methods, from clear-fell through to staged harvesting, and continuous canopy harvesting have different rates of losses. In general, New Zealand uses clear-fell, which generates the largest losses. There are a few examples of alternative harvest methods, such as City Forests' (of Dunedin) who use of staged harvesting for Douglas fir surrounding Dunedin city's drinking water catchment.

Modelling a staged harvest as a mitigation option was considered[8]. The forestry representatives' view was that staged harvest is not as feasible in Southland as it is in other parts of the country. The main reason is that high winds in the region mean that opening up the forest canopy can create an elevated risk of wind throw to the remaining trees. The use of wetlands (natural or constructed), riparian buffers alongside streams sediment traps, or retention bunds to capture sediment are as relevant for forestry as they are for agriculture and some work may be needed on these mitigations in the future.

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[6] Fertiliser is not standard practise in forestry and occurs irregularly. Its use is either site or species specific – usually occurring where there are major deficiencies in the soil or to achieve strong growth early in the rotation.
[7] Kilograms of nitrogen per hectare per year, and kilograms of phosphorus per hectare per year
[8] Douglas fir is a more windfirm species than radiata pine and can be production thinned multiple times to retain canopy cover and reduce sediment risk (Steve Chandler, pers. comm., 2016).

Proposed National Environmental Standard for Plantation Forestry

New Zealand's forestry sector has worked with central government since before 2010 to develop a national environment standard for plantation forestry. If implemented in the form it was proposed then it will replace existing district and regional plan rules with an approach that is intended to give consistency and certainty for plantation forestry across New Zealand while being responsive to local conditions.

The proposed National Environmental Standard for Plantation Forestry (2015) sought to change how plantation forestry activities are managed under the Resource Management Act (1991) by introducing a number of technical standards and rules for activities. The rules focused on eight separate activities that cover the life cycle of plantation forestry: mechanical land preparation, afforestation (the establishment of a stand of trees), earthworks, forest quarrying, river crossings, pruning/thinning to waste, harvesting, and replanting phases of operations.

It was recognised that in some situations there may be unique environmental, social or cultural issues that would require local solutions. Local councils were allowed to be more stringent on matters relating to: the coastal marine area; geothermal and karst protection areas; areas of known cultural or heritage value; significant natural areas and outstanding natural features and landscapes; shallow aquifers (as groundwater systems may be complex in local areas); and the objectives of the National Policy Statement for Freshwater Management.

Consequently, for the purposes of this research it was assumed that the mitigations relevant to forestry in Southland were more likely to be required under the proposed National Environmental Standard for Plantation Forestry (2015) rather than to occur as a result of setting limits for fresh water under the National Policy Statement for Freshwater Management (2017).

Part A: Southland

Part A of this report outlines background information on Southland. It helps explain how Southland's climate and soils influence agriculture and forestry in the region (**Part B**). This information was used in the methodology of this research (**Part C**).

Part A is made up of two main sections:

Section 1 is a general description of the land, water and people (including agriculture and forestry's role in the economy). It includes outlines of the region's 'Freshwater Management Units' where limits for fresh water will be set.

Section 2 gives more detail around Southland's climate and soils because of the importance of these two factors in the development of agriculture and forestry, and their nutrient losses, particularly those from agriculture. It also includes relevant information about climate change, land use capability classes and the region's 'physiographic zones'.

1. Southland

The environment plays a big part in how agriculture and forestry occur in Southland and, in turn, how these sectors continually shape both the local communities and modify the landscape. As primary sectors, agriculture and forestry are particularly reliant on the use of natural resources (e.g. fresh water, land, and biodiversity) in their production systems.

1.1. The Land

Southland is New Zealand's southernmost region and includes most of Murihiku (the southern part of the South Island), which runs north up to the Clutha River in Otago. The region as a whole (including Rakiura/Stewart Island and other offshore islands) has a total land area of 3.2 million hectares (or 12% of New Zealand). Of this total area, 59 percent is land in indigenous vegetation (including alpine areas where there is little vegetative cover) – 42.3 percent of which is within Fiordland and Stewart Island. Where the indigenous vegetation is at the top of a river catchment it protects the headwaters, and where it is further down the catchment, it helps to buffer the effects on water quality from the 38 percent of land that is developed. The developed areas have been extensively modified with the clearance of native forests and vegetation, the drainage of some lowland soils, the introduction of improved pasture, and the straightening of the rivers. The remaining three percent of the region's 'land' area is taken up with surface water (e.g. lakes, rivers and streams).

Southland is shaped by some of the country's most complex geology and it has one of the widest assemblages of soils. The region's northern boundary is marked out by the Livingstone, Eyre, and Garvie Mountains (in Southland) and the Blue Mountains (in Otago). The Southland Syncline (formed by geological faulting) is a geological fold in the earth's surface that creates a thick 'belt' running on a north-west to south-east axis from Lumsden through to the Catlins coast, and is partially buried beneath the Southland Plains. Figure A1 shows the Tākitimu Mountains and the Hokonui Hills (part of the Southland Syncline) dividing northern and southern Southland.

Northern Southland stretches from the Te Anau Basin in the west, through Lumsden, along the Waimea Plains and down to the town of Gore in the east. South from the 'Hokonuis', the Southland Plains extend from the Aparima River in the west, across the Ōreti River to the lower Matāura River. Looking west beyond the Aparima River, is the Longwood Range and further west is the lower Waiau Plains (below the Te Anau Basin). Fiordland lies beyond and is made up of numerous coastal fiords, mountain ranges, and inland lakes. South of the mainland is Stewart Island/Rakiura and a number of smaller offshore islands, which are not displayed in Figure A1 because of a lack of biophysical data.

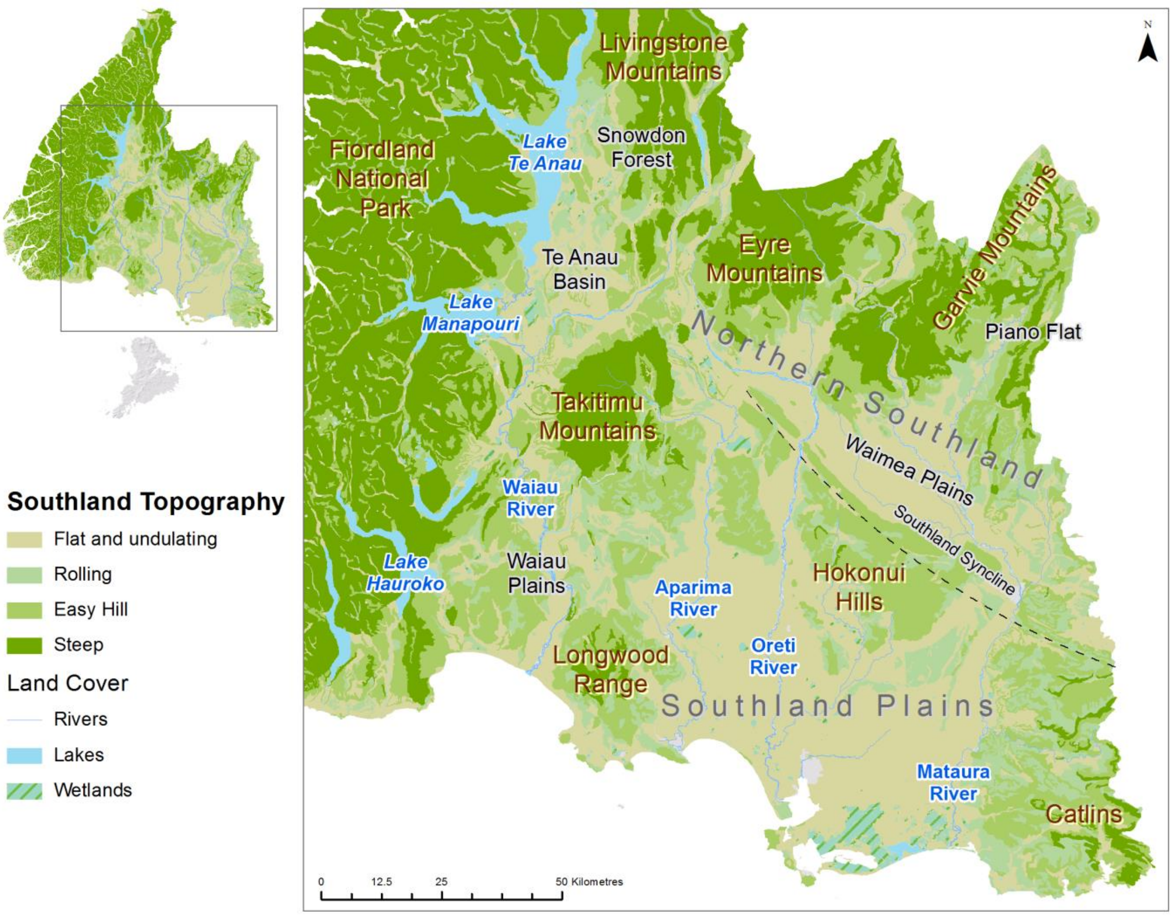

Figure A1: Major landforms in Southland
Source: Produced from the New Zealand Land Resource Inventory

1.2. The Water

Southland contains a large amount of freshwater, both as surface water and groundwater. The region has six of New Zealand's 25 largest lakes (as measured by surface area), including Lakes Te Anau, Manapōuri, and Hauroko (which are also New Zealand's three deepest lakes). There are also tens of thousands of kilometres of rivers and streams, including the Waiau, Aparima, Ōreti, and the Matāura Rivers. Together the catchments of these four rivers drain 1.85 million hectares or 62 percent of the Southland mainland. Numerous other water bodies drain the remaining land to the coast, including Waituna Creek, Waimatuku Stream, and Waikawa, Waihopai, and Pourakino Rivers.

Since European settlement many of these rivers and streams have been confined within stop banks, and in some cases straightened, which has changed their natural flow paths. As a result of this modification, water and nutrient losses now flow more rapidly through the landscape. In addition, water is taken from surface water and groundwater for a range of uses. The most obvious example is the Waiau, where the mean annual flow has been reduced from around 560 to 134 cumecs, or roughly 24 percent of its original natural flow. This water take is to accommodate the Manapouri Power Station, which generates 12 percent (4,800 GW h) of the country's electricity (the largest user of which is Tiwai Point Aluminium Smelter). Figure A2 highlights the extent of surface water in Southland, including any large remnant wetlands. When groundwater is considered as well, few places in Southland are very far from fresh water.

Image A1: Mountain tarn at Key Summit on the Routeburn Track
Source: Adam Brown

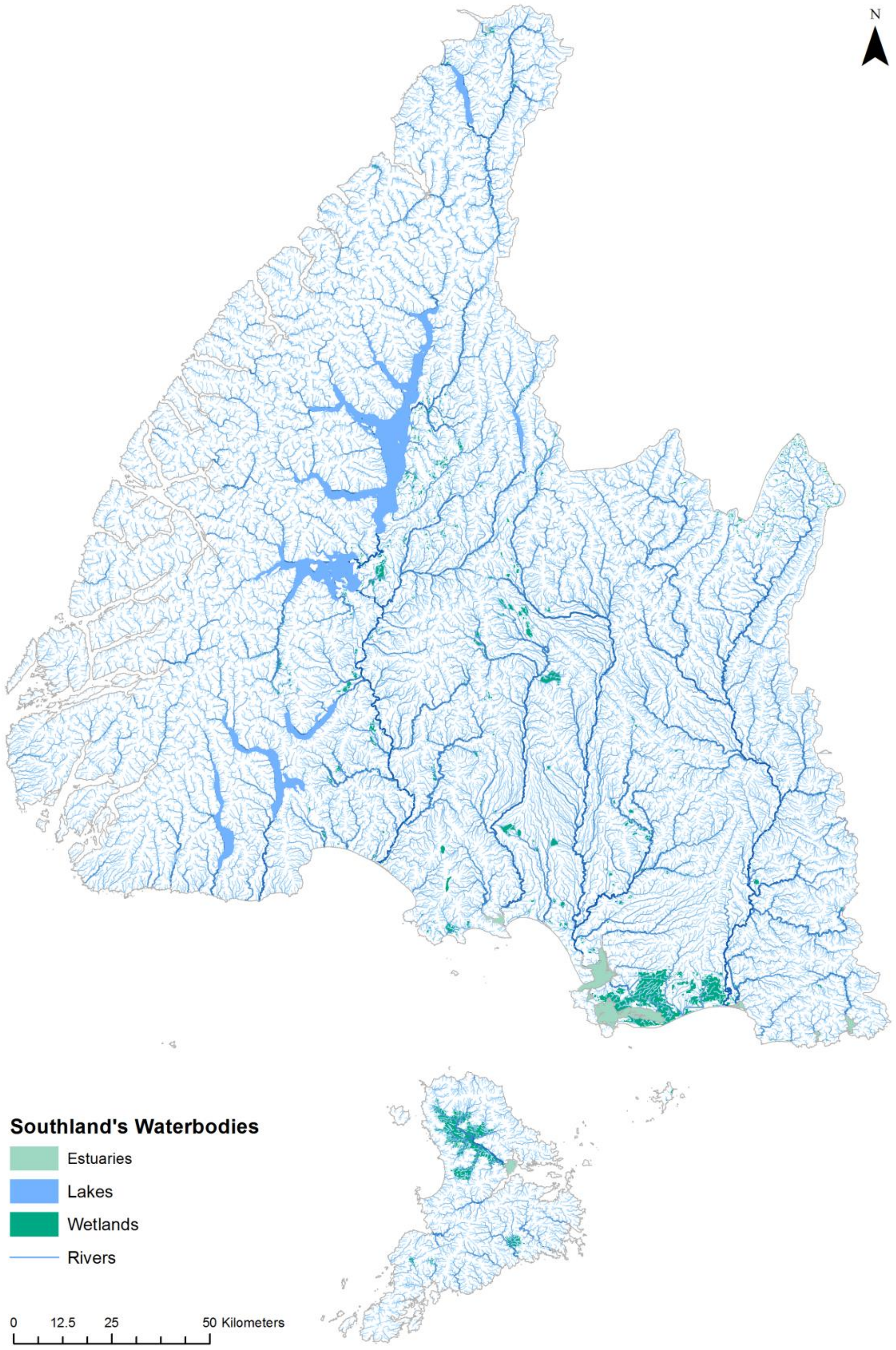

Figure A2: Surface water in Southland
Source: Environment Southland
Note: The rivers are displayed using lighter colours for the tributaries and becoming darker as they flow toward the main stem.

Before the arrival of Māori, around 268,500 hectares of land in Southland were in wetlands and swamps, mostly across the Southern Plains (Figure A3). Wetlands perform a vital cleansing role in the environment – they catch and take up nutrients, and spread and retard (or slow down) the flow of water, allowing sediment to drop out of its suspension. Wetlands are also important connectors between surface water and groundwater. The median static water table in Southland is just 2.4 metres below ground level, with many soils in direct contact with groundwater.

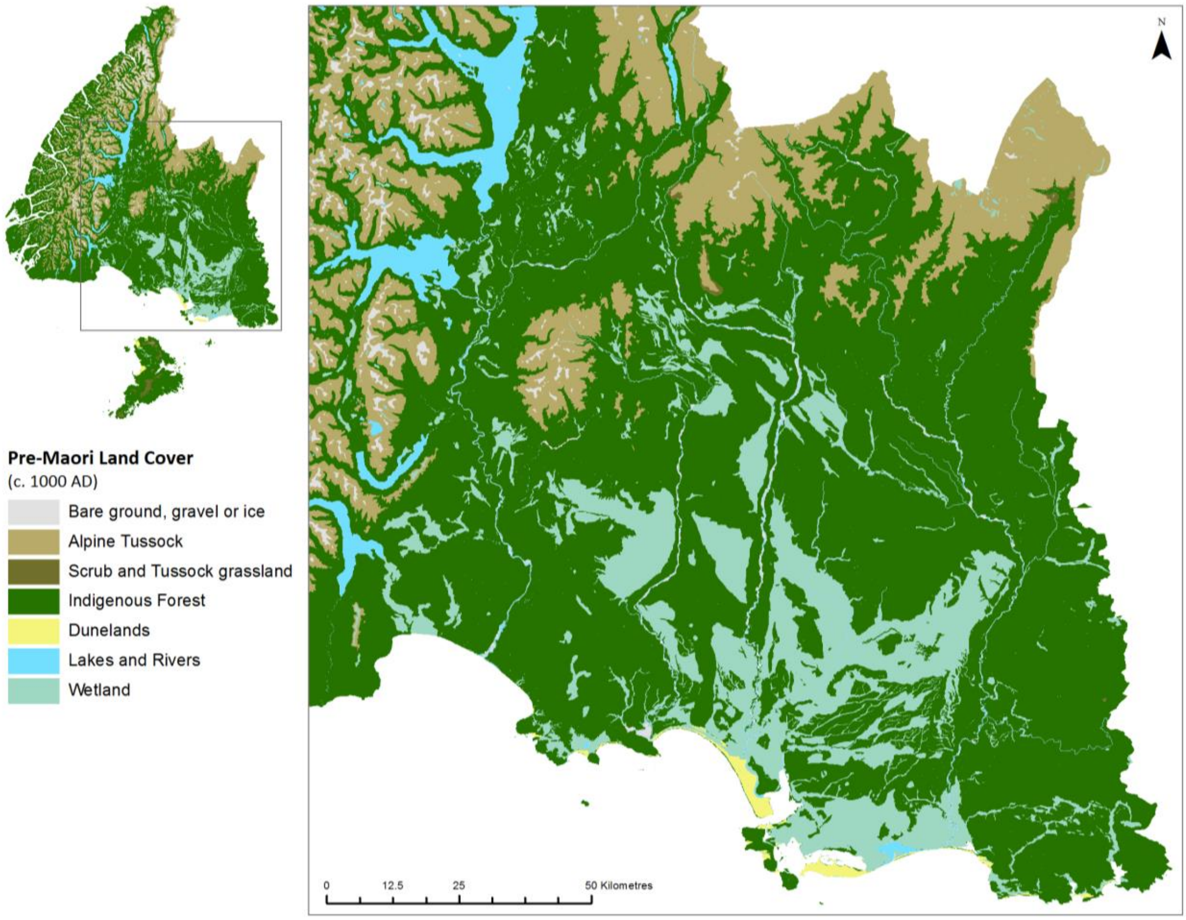

Figure A3: Pre-Māori land cover in Southland c.1000 AD
Source: Pearson and Couldrey (2016)
Note: Land Cover is introduced and explained in more detail in Part B, Section 1.3.

In lowland Southland, wetlands originally covered roughly half of the area (Clarkson, Briggs, Fitzgerald, Rance, & Ogilvie, 2011). Over the years, these wetlands have been drained using extensive networks of tile and mole drains for the development of agriculture (Figure A4). Since 1840, the area of wetlands on land now in private ownership is estimated to have reduced from around 220,000 hectares to 9,650 hectares (or 3.6% of the original area) by 2007 and to 8,486 hectares (or 3.2% of the original area) by 2015 (Dalley & Geddes, 2012; Ewans, 2016). The draining of wetlands has increased pressure on the environment by making more land available for use while reducing the environment's natural capacity to attenuate nutrient losses from this land. As well, the installation of tile and mole drains has created direct channels (or pathways) for losses of nutrients to enter surface water, bypassing some natural processes.

The drainage of wetlands, and lowland soils more generally, has changed the regional hydrology across these areas so that there is comparatively little time for substances, such as nutrients, to attenuate before they reach water bodies. Similar large scale changes in hydrology have occurred in other parts of the world where naturally low permeability and high water tables required extensive networks of subsurface drainage to make land suitable for agriculture (e.g. Illinois, USA and Manitoba, Canada).

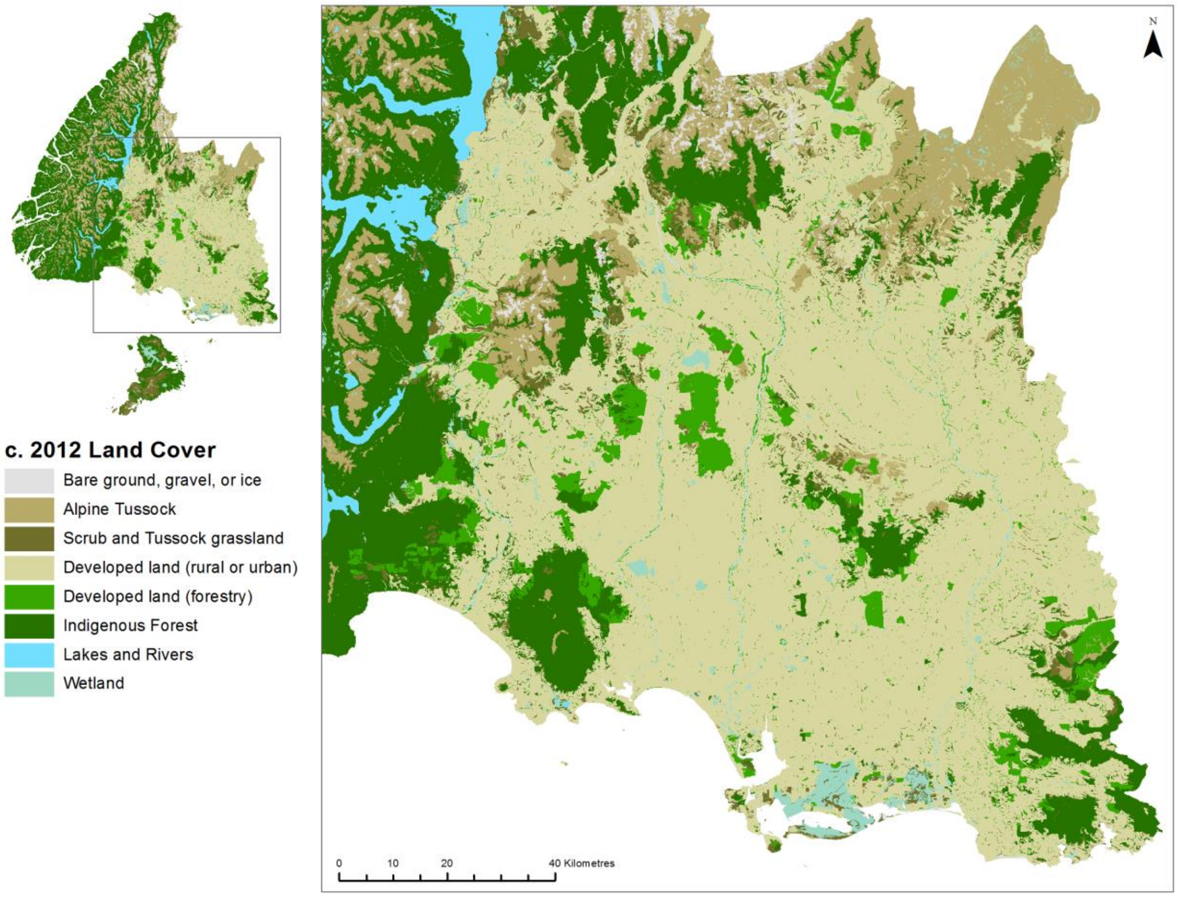

Figure A4: Land cover in Southland c.2012
Source: Pearson and Couldrey (2016)

In addition to its wetlands, Southland has a mosaic of unconfined, shallow groundwater aquifers that exchange groundwater to surface water relatively quickly. Roughly 47 percent of all of the water in Southland streams is groundwater from these aquifers (the mean base flow index for Southland is around 0.47). It is highly variable across the region, with lowland streams having a much higher proportion of groundwater than alpine streams. The shallow groundwater table, together with a cool humid climate, mean that groundwater within unconfined aquifers are young, with an average residence time or age of less than ten years. Elsewhere in New Zealand aquifers are often much deeper and can be up to several thousand years in age (e.g. Canterbury and large areas of the Waikato). Notable exceptions in Southland are a small area within the Te Anau Basin and a few lowland aquifers hosted by very old alluvial formations, such as the Luggate Shotover Formation (underlies most of the Waimea Plains and has remnants along the Matāura Valley). The region has a small volume of potable (or drinkable) groundwater, compared with other regions, because its fluvio-glacial gravels form only a thin veneer over poorly permeable basement rocks. Groundwater within basement rock tends to be poorly potable and needs treatment to be used in agriculture.

The consequences of the quick exchange between groundwater and surface water are there is often limited natural water storage in areas of developed land, and nutrient losses move through the landscape rapidly (i.e. there are short lag times). Accordingly, the modification of Southland's lowland hydrology favours the rapid transport of nutrients, sediment and microbes, reducing the time available for natural processes to attenuate these substances before they reach water bodies.

Eventually, the region's fresh water flows into 24 estuaries before entering Foveaux Strait and the Southern Ocean. Between Te Wae Wae Bay (at the mouth of the Waiau River) and the Catlins (east of the Matāura River mouth), estuaries occupy 43 percent of the southern coastline (Robertson & Stevens, 2008). There are four basic estuary types: tidal lagoons (e.g. New River Estuary), tidal rivers (e.g. Waimatuku), coastal embayments (e.g. Bluff Harbour) and fiords (e.g. Milford Sound). In Southland, tidal lagoons dominate the river catchments with developed land. This type of estuary contains high levels of biodiversity and tends to retain loads of nutrients and fine sediments. Some tidal lagoons and tidal river estuaries have mouths that close and open to the sea intermittently (e.g. Waituna Lagoon).

Image A2: Pleasure Bay, New River Estuary
Source: Michael Killick

Overall, Southland's water and land is highly connected, in comparison to other regions. The environment has influenced the development of agriculture and forestry and, in turn, it has been altered by the expansion of these sectors. Modification of Southland's environment, combined with its naturally short lag times, means that water (and the substances that are carried in it) now flows more quickly through the landscape, with fewer opportunities for attenuation.

1.3. The People

As of 30 June 2014, around 96,500 people live in Southland (2.16% of New Zealand's population) (Statistics New Zealand, 2015). Of all the people in Southland, just over 30 percent live in rural areas, which is high for New Zealand (where 13% of the population is rural). Most people in rural areas are either in areas that are 'highly rural/remote' or 'rural with low urban influence'. Figure A5 shows the proportions of Southlanders living in rural and urban areas compared to New Zealand as a whole. The relatively high proportion of people living rurally reflects Southland's reliance on primary sectors, and particularly agriculture. It also highlights the strong interdependence between urban and rural communities across Southland, with most urban centres existing to service the surrounding rural areas and rural areas being reliant on services in these urban centres.

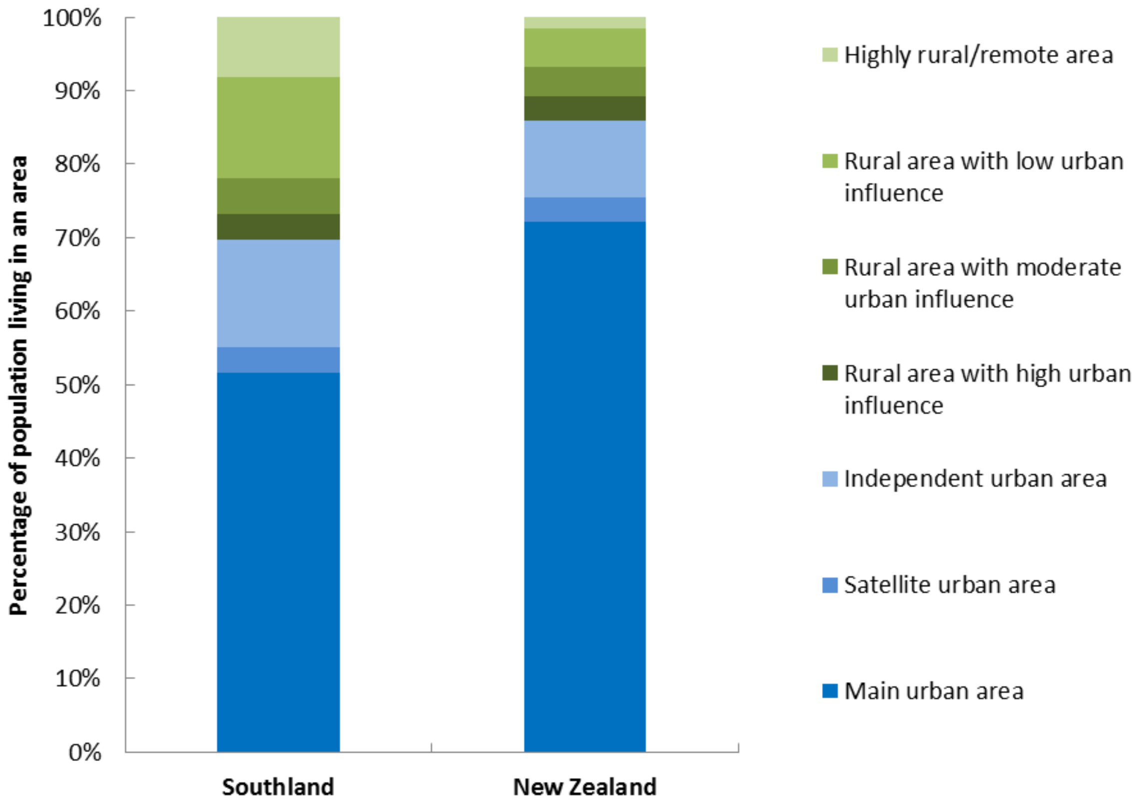

Figure A5: Urban and rural profiles for Southland and New Zealand
Source: StatsNZ

Within the region, Southlanders live in one of three territorial authorities: Southland District Council, Gore District Council and Invercargill City Council. Figure A6 shows the extent of these three councils in Southland – collectively the boundaries of the three councils roughly fit within the regional boundary (there are some places e.g. the Kaiwera Stream where they do not align). Invercargill City and Gore District are either largely urban or rural areas with high urban influence, while Southland District is largely rural or remote areas. Although agriculture and forestry occur mainly in the Southland District and, to a lesser extent, in the Gore District, Southland's largest urban areas, Invercargill City and Gore, are dependent on the fortunes of these primary sectors.

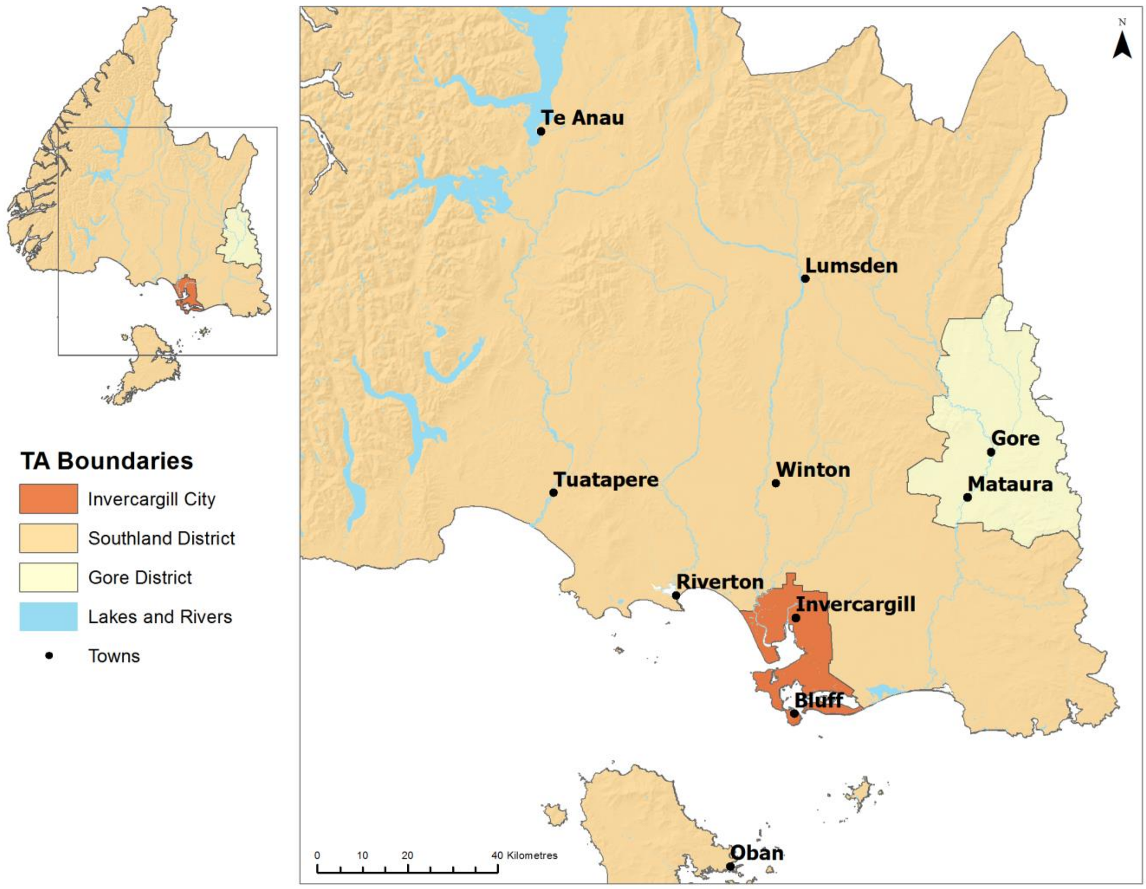

Figure A6: Territorial authority areas focused on the developed land in Southland
Source: Environment Southland

In Southland, ten percent of the population are Māori (2013 Census) (Statistics New Zealand, Released from October 2013 to June 2015). Tangata whenua are Ngāi Tahu, Kati Mamoe and Waitaha, and there are four rūnanga: Te Rūnaka o Waihōpai; Te Rūnanga o Awarua; Te Rūnanga o Oraka Aparima; and Te Rūnanga o Hokonui.

1.3.1. The Economy

Southland has a small, narrow-based economy focused on its primary sectors, particularly agriculture, its related manufacturing sectors and increasingly tourism. In 2012, the value of goods and services produced in Southland, or total regional Gross Domestic Product (GDP), was just over $5 billion. Although Southland's GDP has fluctuated since, this figure generally indicates the size of the region's economy. This section gives an overview of agriculture and forestry within Southland's economy. A full analysis of the economy and its use of water is available in Part 1 of *Southland Region: Regional Economic Profile and & Significant Water Issues* (Market Economics, 2013).

Southland's economy has two main features that single it out from most other regional economies around New Zealand. First, it is a considerable distance from New Zealand's three main urban centres: Auckland, Wellington and Christchurch. Second, it is almost completely reliant on the use of natural resources, either directly or indirectly, particularly water. These two features both constrain Southland's economy and provide opportunities. The nature of the economy is not expected to change, at least over the short to medium-term (Market Economics, 2013).

Between 2001 and 2014 the regional economy's growth fluctuated markedly. Figure A7 shows the annual percentage change in regional GDP year on year over this time period. In 2013, the median income in Southland for people aged 15 and over was $29,500, which was 3.5 percent higher than the national median of $28,500. (Statistics New Zealand, 2013).

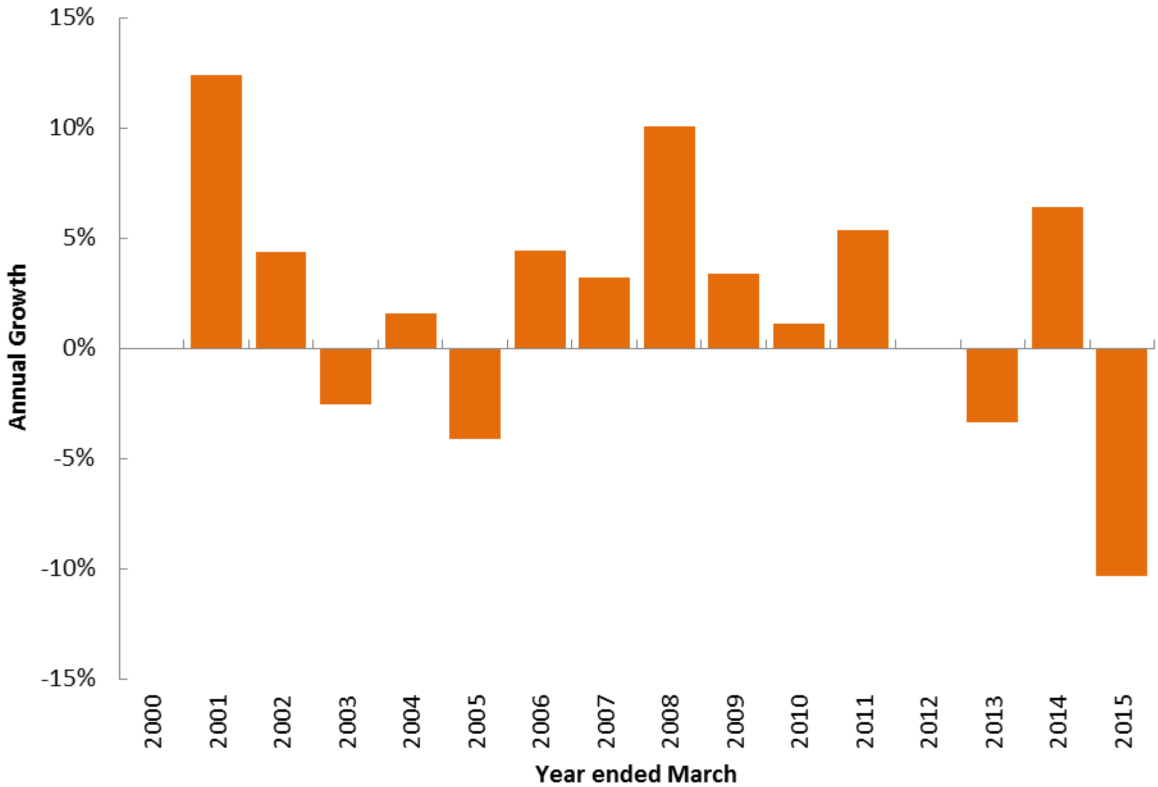

Figure A7: Percentage growth in real GDP for Southland 2001-2015
Source: StatsNZ Regional GDP series, RBNZ M1 series

GDP is a partial measure of economic activity and while it indicates an economy's size, it does not gauge its quality, which is a more subjective judgement. GDP includes market transactions in an economy, such as interest payments on borrowings, but it does not include non-market transactions, like housework or volunteerism. Regional GDP is used here because it is a well-known indicator (with well-known limitations) and the lack of alternatives at a regional scale. It needs to be used alongside other indicators to fully understand the economy's resilience to changing conditions, its sustainability in terms of resource use, and its contribution to people's standards of living and outcomes for communities across Southland.

To date, Southland's economy has been heavily reliant on agriculture. The agriculture sector in Southland is the third biggest in New Zealand (as measured by regional GDP), after Canterbury and Waikato. For the year ended March 2012, agriculture directly[9] contributed $1.1 billion to Southland's GDP. In Southland, agriculture's share of regional GDP was 21.9 percent, which was double its share in most other regions, including Canterbury (where it was 7.5%) and Waikato (where it was 10.9%). Figure A8 shows the agriculture sector's share of regional GDP and the value in dollar terms. As a whole, agriculture's contribution to the New Zealand economy for the year ended March 2012 was around five percent of national GDP.

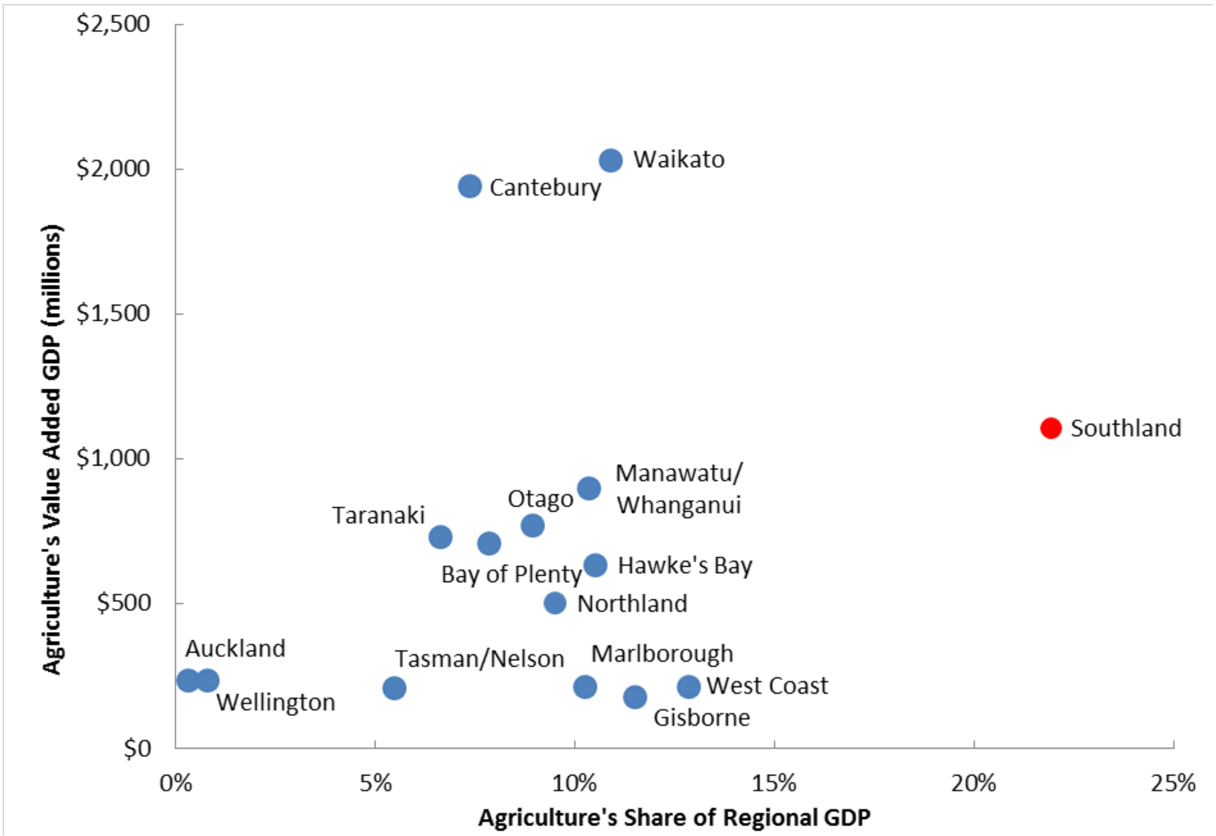

Figure A8: Agricultural sector GDP by region March 2012
Source: StatsNZ Regional GDP series

[9] It does not include its impact up to or beyond 'the farm gate', which are considerable (i.e. the interdependencies between agriculture and manufacturing or agriculture and the service sectors of the economy).

Southland's reliance on agriculture becomes even more apparent when the region's population size is considered. Figure A9 shows agricultural sector's share of regional GDP per capita and highlights Southland as an outlier, in comparison to other regions.

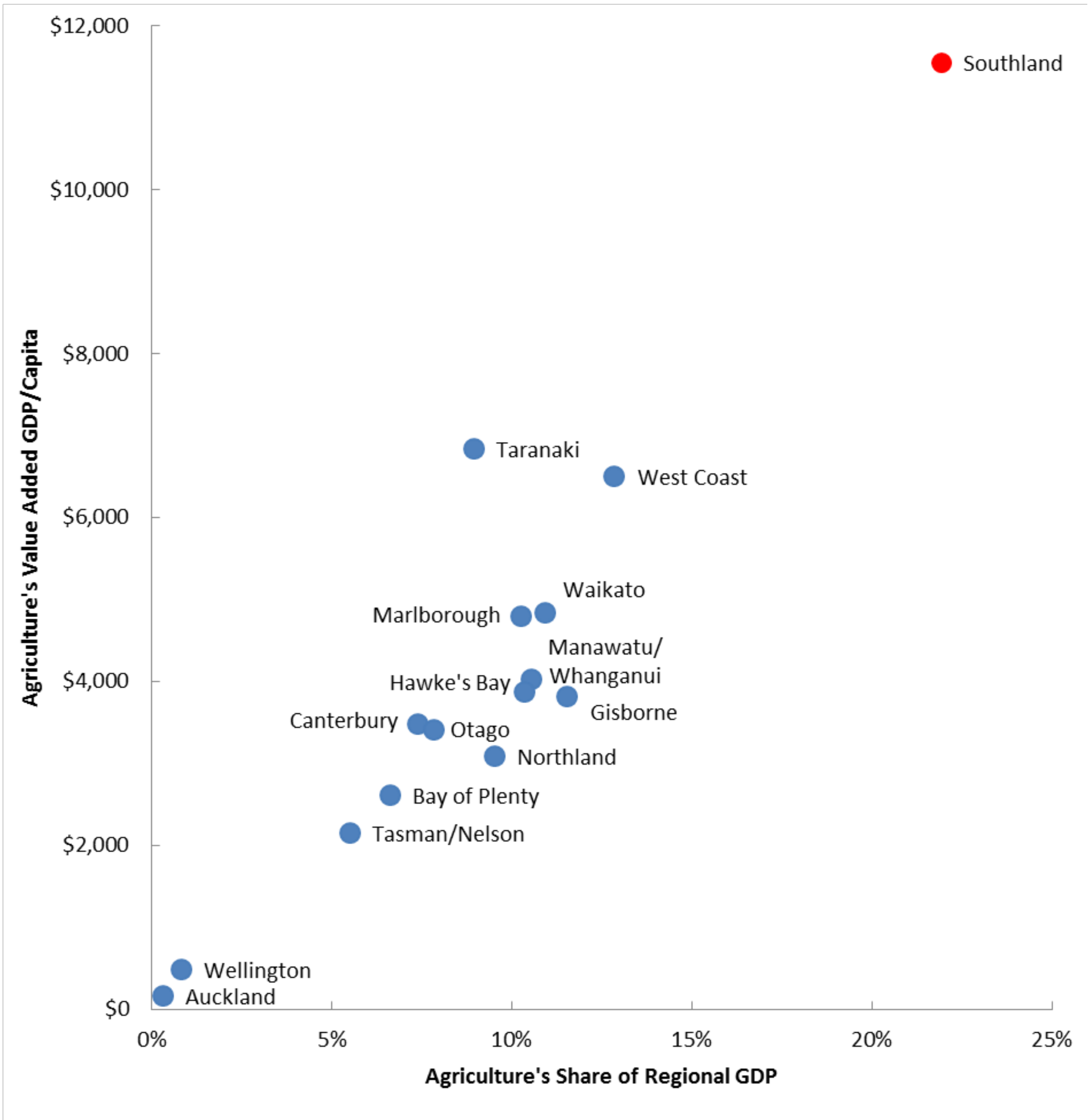

Figure A9: Agricultural sector GDP per capita by region March 2012
Source: StatsNZ Regional GDP series

The influence of agriculture and forestry flows through the rest of Southland's economy in a multitude of ways, from agricultural support services, to manufacturing and consumer spending. In Southland, the value-added from sheep, beef and arable industries in 2011 was $279 million. When manufacturing is included, it increases more than three-fold to a total of $931 million (Market Economics, 2013). The value-added from the dairy industry is $363 million, and when manufacturing is included, it increases to total $459 million. The value-added from horticulture is $10 million. By comparison, forestry's value-added is $35 million, increasing to total $83 million with manufacturing. Support services to agriculture and forestry, such as banking and legal services or contractors, are additional to these figures.

Although regional GDP indicates the size of a sector (both directly and indirectly) in an economy, its benefit to Southland (rather than to New Zealand as a whole) is likely to be influenced by patterns of ownership[10]. An important measure of a sector's benefit to a region is employment. In Southland, across the agricultural sector in 2014 there were 9,456 jobs[11] on-farm and just under 14,000 jobs when related processing and manufacturing industries are included (for example meat processing and dairy product manufacturing).

Figure A10 shows employment by agricultural industry (shown by the darker colour on each bar) and their directly related manufacturing industries in Southland (shown by lighter colour on each bar) for the year ended March 2014. In the graph, the horticulture growers include processing. These figures do not include support services to agriculture and forestry.

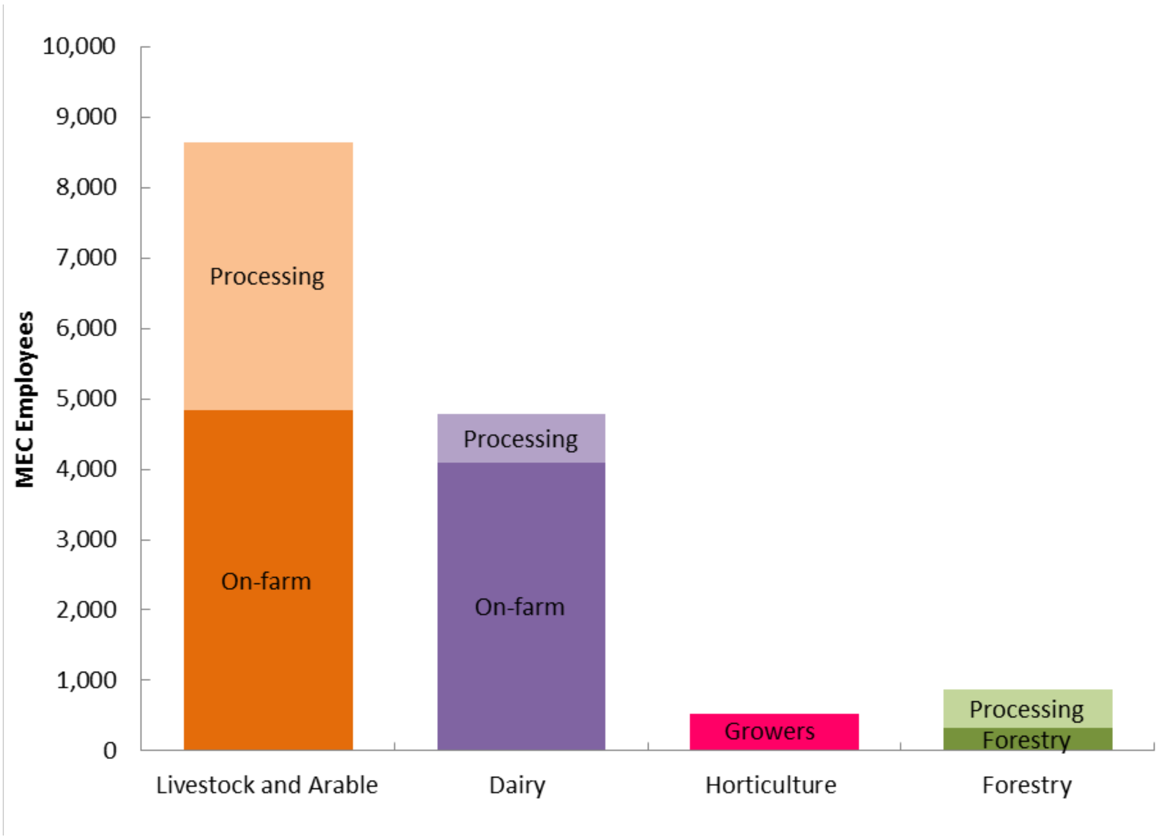

Figure A10: Employment by industry and related manufacturing 2014
Source: Market Economics ANZSIC industry classifications data

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[10] There is evidence to show that smaller-scale, locally owned and operated farms are often connected with greater community wellbeing than larger-scale corporate farm, for example: Fairweather (1986) and Lobao and Stofferahn (2007).

[11] All of the figures for 'jobs' reported here are estimated using Modified Employment Counts (MEC) (Market Economics, 2013), which is a measure based on Employee Counts data from Statistics New Zealand's Business Frame. Employment Counts is a head count of salary and wage earners for a reference period. It includes most employees but does not capture all working proprietors – people who pay themselves a salary or wage (or 'drawings'). Modified Employment Counts includes estimates of the number of working proprietors.

Within agriculture, there were 4,800 jobs (or 8.7% of the workforce) in the drystock and arable industries and the number of jobs increases to a total of 8,642 when manufacturing is included (or 15.5% of the workforce). There were around 4,100 jobs (or 7.4% of the workforce) in the dairy industry and the number increases to total 4,800 jobs (or 8.6% of the workforce) with manufacturing. Overall, there tend to be more jobs in dairy farming than sheep and beef farming on a per hectare basis, but more jobs in meat processing than milk processing.

There are just over 500 jobs in horticulture and another 15 jobs in manufacturing (or a total of just under 1% of the workforce). By comparison, there were 321 jobs in the forestry sector and another 556 jobs in wood processing (a total of 877 jobs, or 1.6% of the workforce). The value-added and employment figures from industries such as horticulture and forestry (commercial plantation and indigenous) are considerably more than their land areas in the region otherwise indicate (refer to Part B: Section 1.1).

Over the last 20 years, agriculture's contribution to Southland's economy has generally been increasing, with the increase being driven by the rapidly expanding dairy industry. Figure A11 shows the growing gap between GDP per capita from agriculture in Southland and New Zealand as a whole since 2006. In the year ended March 2012, Southland's GDP per capita directly from agriculture (i.e. at the farm-gate) was roughly five times higher than the New Zealand average.

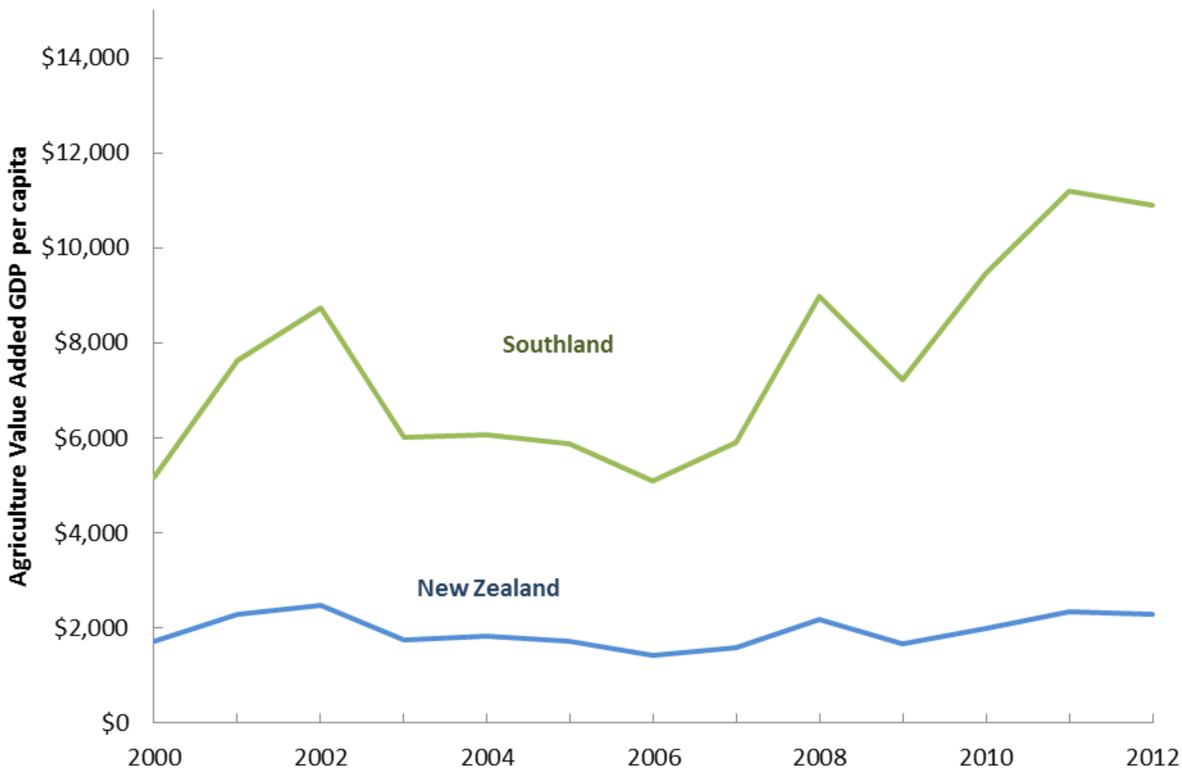

Figure A11: Agriculture GDP per capita for Southland and New Zealand 2000-2012
Source: StatsNZ Regional GDP series

Southland's high proportion of GDP per capita from agriculture means that its economy is far more reliant on this sector than the New Zealand economy is as a whole, and it is becoming more so over time. The Southland economy's reliance on agriculture means it is relatively exposed to external forces, in particular changes in the currency exchange rate and commodity prices. From 2000 to 2014, the regional economy grew from just over $3 billion to around $5 billion but fluctuated markedly from one year to the next. Figure A11 (above) shows the fluctuations in growth between 2000 and 2012.

In addition to exposing the economy to external forces, the agricultural sector is reliant on natural resource use on both the input and output sides of its production systems. It is estimated that most of the demand for fresh water in the future is likely to come from agriculture and dairy manufacturing, particularly to attenuate their by-products (Market Economics, 2013). It has been found that there is a positive relationship between increases in milk production and losses of nitrogen, in particular, although losses vary considerably depending on management, climate (and particularly rainfall) and soils (Monaghan & De Klein, 2014).

Overall, Southland's reliance on agriculture means that changes in people's use of water – either as a water take or where waste substances end up in water – as a result of setting limits for fresh water are likely to have greater impacts on local communities than similar changes in other regions.

Image A4: Planted gullies and riparian margins, near Glencoe
Source: Matt Couldrey

1.4. Freshwater Management Units

Under the National Policy Statement for Freshwater Management (2017), an important step towards setting limits for fresh water in Southland was to divide the region spatially into five Freshwater Management Units (or FMUs) around its water bodies. FMUs are the geographical areas where community processes will occur and where the use of water may need to change. These limits will be designed around the community's values for water, including ecosystem health and human health. These two values apply to all water bodies across New Zealand under the National Policy Statement for Freshwater Management (2017).

Freshwater management in Southland will consider and recognise Te Mana o te Wai. Te Mana o te Wai is the integrated and holistic wellbeing of a freshwater body. Upholding Te Mana o te Wai acknowledges and protects the mauri (life force) of the water. In using water there must be provision for Te Hauora o te Taiao (the health of the environment). Te Hauora o te Wai (the health of the water body) and Te Hauora of te Tanagata (the health of the people).

Running from West to East, Southland's five FMUs are: *Fiordland and Islands*; *Waiau – Waiau Lagoon*; *Aparima and Pourakino – Jacobs River Estuary*; *Ōreti and Waihopai – New River Estuary; and Matāura – Toetoes Harbour*. Figure A12 shows the five FMUs that are described in the following sections.

The Fiordland FMU covers western Fiordland and the offshore islands, including Stewart Island/Rakiura. It is predominantly land in natural vegetation held within national parks. The remaining four FMUs (Waiau, Aparima, Ōreti and Matāura) are based broadly on Southland's four major river catchments – and each FMU also includes a number of smaller coastal river catchments that are not hydraulically connected to the main river in the area. Their coastal boundary is at the mouths of the estuaries, with regard will be given to the wider coastal environment through the use of existing monitoring sites. In contrast to the Fiordland FMU, these four FMUs are largely developed land and primarily agricultural and forestry – although 36 percent of the region's land in natural vegetation is located within these four FMUs.

All of Southland's FMUs include Statutory Acknowledgements by the Crown under the Ngāi Tahu Claims Settlement Act (1998) and some FMUs also contain Water Conservation Orders (WCOs). The Ōreti and Matāura FMUs include the RAMSAR Waituna-Awarua Wetland of International Importance. The Fiordland and Waiau FMUs include Fiordland National Park, which is the southern end of the UNESCO Te Waihipounamu – South West New Zealand World Heritage Area.

Southland's FMUs were used as the basis for determining how the case study farms for the dairy industry and the sheep and beef industry were distributed across the region. For these industries, the number of farms within an FMU was chosen to line up with the industry's land area within that FMU out of its total land area in Southland. For example, if 30 percent of an industry's land area in Southland is in the Waiau FMU then roughly 30 percent of its case study farms were in this FMU. More information on land uses in Southland can be found in Ledgard (2013) and Pearson and Couldrey (2016).

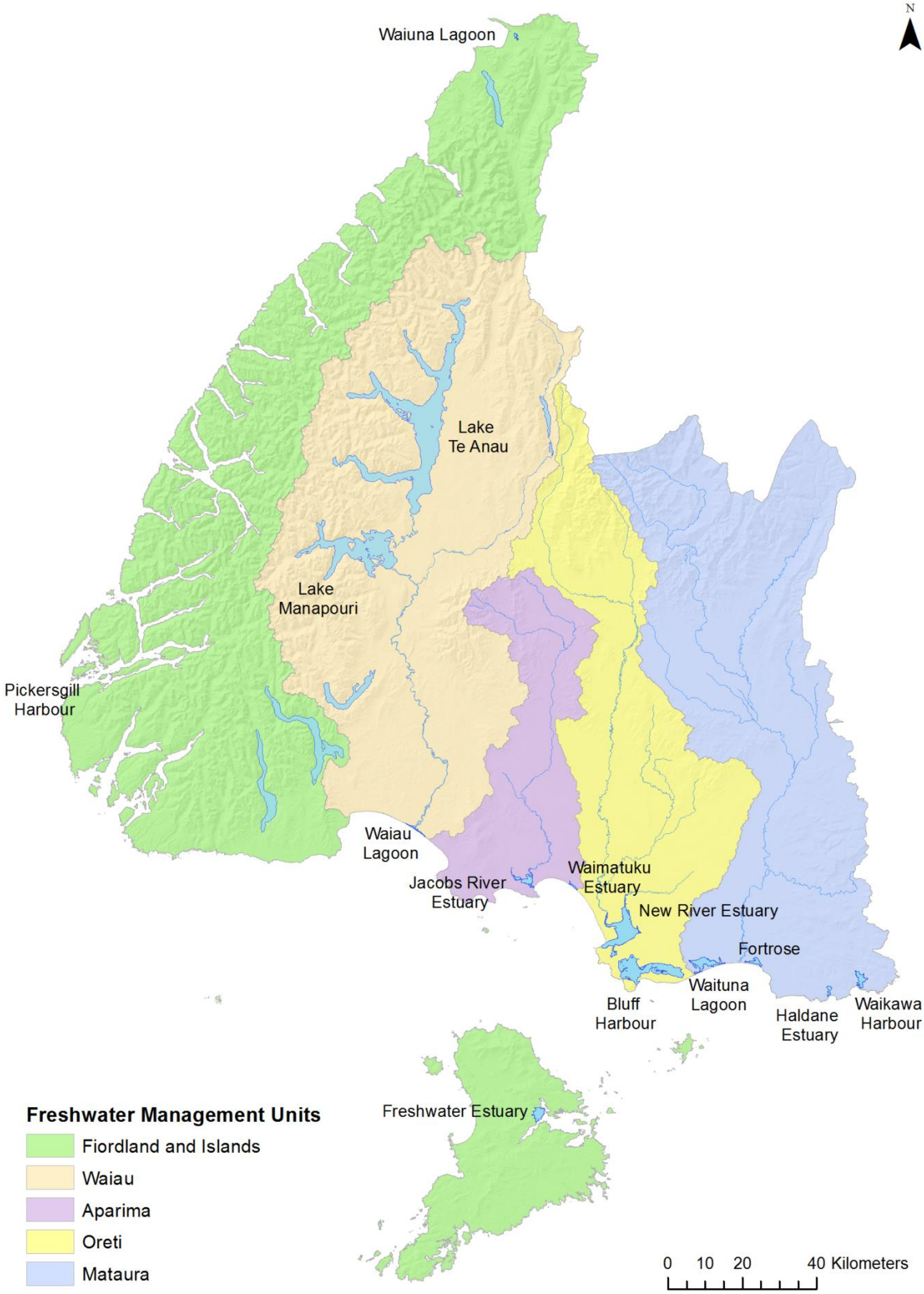

Figure A12: Freshwater Management Units in Southland
Source: Environment Southland

The tables and maps in the following sections are based on the main land use activities occurring on a property. These land uses activities are explained in more detail in Part B, Section 1.

Sheep and Beef: Sheep and Beef; Sheep; Beef; and Mixed Sheep, Beef and Deer;

Dairy: Dairy; Dairy Support; and Dairy Support and Other Livestock;

Deer: Mixed Sheep, Beef, and Deer (Majority Deer); and Specialist Deer;

Arable: Arable and Mixed Livestock; and Specialist Arable (not including crops grown for winter grazing);

Other: Livestock Support; Small Landholdings (5-40 hectares); Lifestyle (<5ha); Other Animals; Sheep Dairy; Horticulture; and Unknown Pasture;

Forestry: Plantation Forestry (Exotics); and Indigenous Forestry; and

Urban: Industry and Airports, Commercial, Residential, Road and Rail, Public Use (e.g. halls, schools).

1.4.1. Fiordland and Islands

The Fiordland and Islands FMU extends over west Fiordland, Stewart Island/Rakiura and the region's outlying islands. The FMU covers an area of around 1,073,400 hectares (33.5% of the region), most of which is land managed by the Department of Conservation, and includes part of Fiordland National Park and all of Rakiura National Park. The FMU lies entirely within Southland District and is the least populated of Southland's five FMUs, with 534 residents[12], most of whom live on Stewart Island. The main towns are Oban and Milford Sound/Piopiotahi and there are a small number of water takes, wastewater and/or stormwater schemes. Table A1 gives estimates of the extent of land use activities for this FMU. Around 1,500 hectares, or 0.1 percent of the land, is developed as a handful of farms (mainly on off shore islands) and multiple tourism operations.

According to Ngāi Tahu tradition the fiords were formed by Tū Te Rakiwhānoa, who through a powerful karakia and his adze blade, carved the entire Fiordland coast. Milford Sound/Piopiotahi has great spiritual value for Māori – Piopiotahi refers to a lone piopio, a long-extinct native bird, who it is said flew to Milford Sound in mourning at the death of Maui. Milford Sound was also the destination of ancient Māori treks for a precious rare form of pounamu, tangiwai or bowenite. Under the Ngāi Tahu Claims Settlement Act 1998, a Statutory Acknowledgement applies to Hananui (Mount Anglem), Lake Hauroko, Toi Toi Wetland, Whenua Hou and Tautoko as well as a tōpuni for Tūtoko, to recognise the significance of these areas. Figure A13 shows the distribution of land uses within the Fiordland and Islands FMU.

The Fiordland FMU has numerous lakes and coastal water lakes (all natural state), including Lake Alabaster, lake Hauroko, Lake Poteriteri, Lake McKerrow and Hakapoua. The seasonal influx of tourists to Milford Sound is at least 850,000 people (K. Murray, pers. comm., 2018). Also, four of New Zealand's eight Great Walks (the Kepler, Milford, Routeburn and Rakiura Tracks) are in either Fiordland or Stewart Island and Southland has large numbers of visitors for recreational tramping. In total, there were 400,000 international visitors to Fiordland to the year end of June 2016.

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[12] Statistics New Zealand (2013): numbers may vary as census meshblocks cross FMU boundaries so some may have been counted twice.

Table A1: Agriculture, forestry and urban areas in the Fiordland and Islands FMU

Land Use	Total land in FMU (ha)	Share of developed land in FMU	Share of total land use in region that is present in this FMU	Number of properties in FMU
Sheep and beef	592	39.5%	0.1%	6
Dairy (incl. support)	0	0%	0.0%	0
Deer	4	0.3%	0.0%	1
Arable	0	0%	0.0%	0
Horticulture	0	0%	0.0%	0
Other	489	32.6%	-	55
Forestry	0	0%	0.0%	0
Urban	414	27.6%	0.9%	543
Totals	**1,498**	**100.0%**		**605**

Source: Southland Land Use Map, Pearson and Couldrey (2016)
The 'other' category covers livestock support, small landholdings and lifestyle blocks, other animals, horticulture, and 'unknown' pasture.

Image A4: Milford Sound, Fiordland
Source: Simon Moran

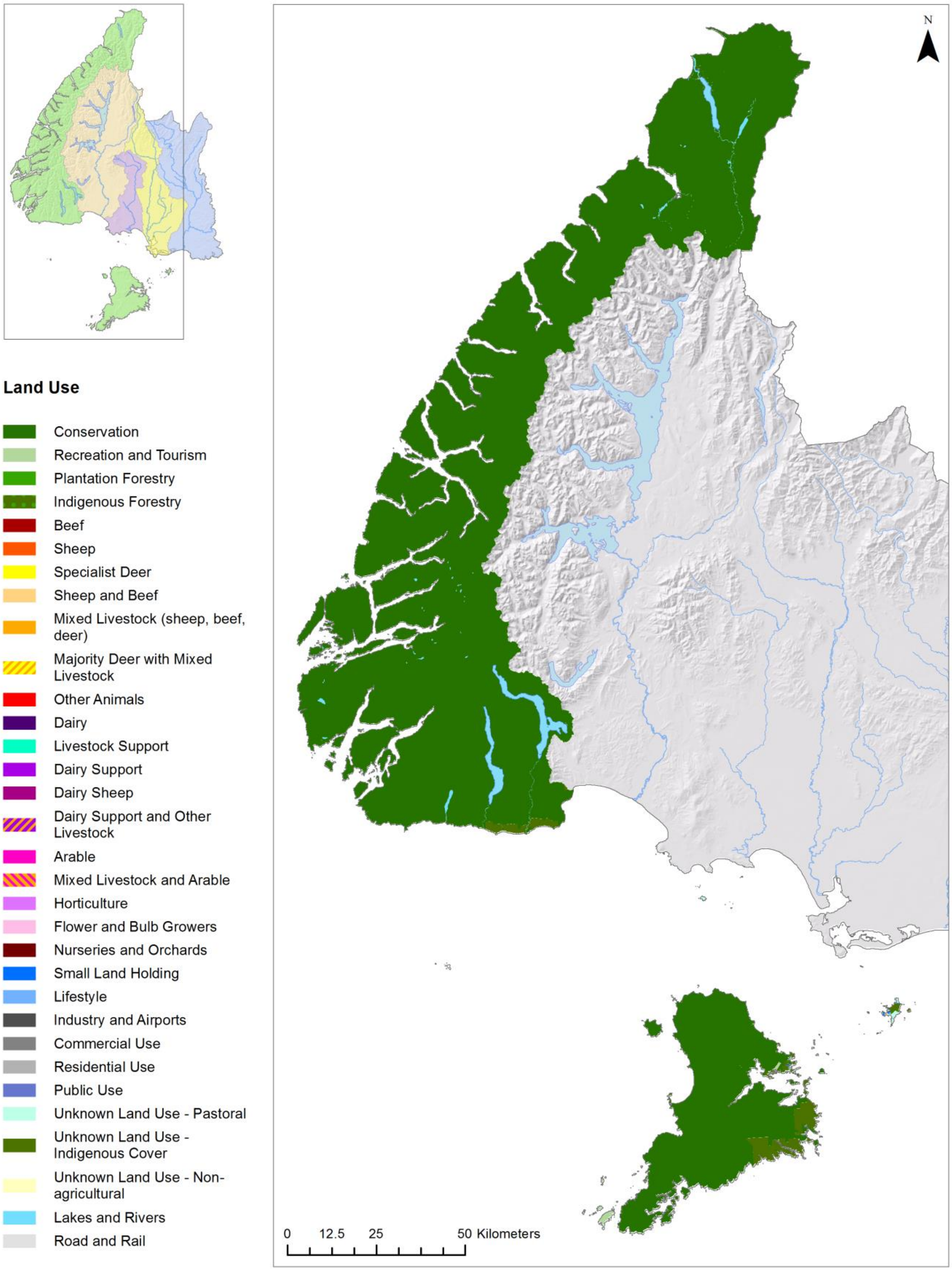

Figure A13: Land use within the Fiordland and Islands FMU
Source: Southland Land Use Map, Pearson and Couldrey (2016)

1.4.2. Waiau – Waiau Lagoon

The Waiau FMU covers around 862,700 hectares (26.9% of the region) and is the largest of the four main developed FMUs in Southland. It contains a large amount of public conservation land, including part of Fiordland National Park in the west and the Tākitimu Conservation Area in the east. Around 240,000 hectares, or 28 percent of the FMU, is developed land. The FMU lies entirely within the Southland District, there are around 5,044 residents (or less than 1 people/km^2) and a number of towns including Tuatapere (population 558), Te Anau (population 1,911), and Manapōuri (population 228), with water takes, wastewater and/or stormwater schemes. The FMU contains tourism activities and large drystock properties, and a smaller area of dairy farming. Table A2 gives estimates of land use activities for the Waiau FMU.

Table A2: Agriculture, forestry and urban areas in the Waiau FMU

Land Use	Total land in FMU (ha)	Share of developed land in FMU	Share of total land use in region that is present in this FMU	Number of properties in FMU
Sheep and beef	148,113	61.9%	19.4%	272
Dairy (incl. support)	19,450	8.1%	7.4%	64
Deer	15,938	6.7%	36.8%	68
Arable	16	0.0%	0.1%	1
Horticulture	26	0.0%	0.0%	2
Other	9,805	4.1%	-	397
Forestry	32,129	13.4%	34.3%	75
Urban	13,764	5.8%	29.9%	3,173
Total	**239,242**	**100.0%**		**4,052**

Source: Southland Land Use Map, Pearson and Couldrey (2016)

The Waiau FMU includes Lake Te Anau, Lake Manapouri, Green Lake and Lake (all natural state), and fresh water that ends up in Te Waewae Lagoon. There is a Marine Mammal Sanctuary in Te Waewae Bay, and a strong whitebaiting community. The Waiau also contains the Monowai and Manapōuri Power Schemes. The Manapouri scheme has reduced the mean annual flow of the Waiau River below the Mararoa Weir from around 560 cumecs (cubic metres per second), in the years before the scheme, to 135 cumecs, for the years between 2006 and 2016. This reduction in flow is altering the environment in the Lower Waiau Catchment and Te Waewae Lagoon. The Waiau Trust leads habitat enhancement for fisheries and wildlife in the Waiau river catchment (Jan Riddell, pers. comm., 2016).

Under the Ngāi Tahu Claims Settlement Act 1998, a Statutory Acknowledgement applies to the Waiau River, Moturau (Lake Manapōuri), Te Anau (Lake Te Anau), Manawapōpōre/Hikuraki (Mavora Lakes) and a tōpuni[13] for the Tākitimu Range. The name Waiau (wai: water, au: current) comes from

[13] The concept of Tōpuni comes from the traditional Ngāi Tahu tikanga (custom) of persons of rangatira (chiefly) status extending their mana and protection over a person or area by placing their cloak over them or it. A Tōpuni now confirms and places an 'overlay' of Ngāi Tahu values on specific pieces of land managed by DOC.

the swirling nature of its waters. The river was a major travel route for pounamu that connected Southland, Fiordland and the West Coast. Numerous archaeological sites and wāhi taonga are evidence of the history of occupation and use of the river by Ngāi Tahu and Ngāti Māmoe. Figure A14 shows the distribution of land uses within the Waiau FMU.

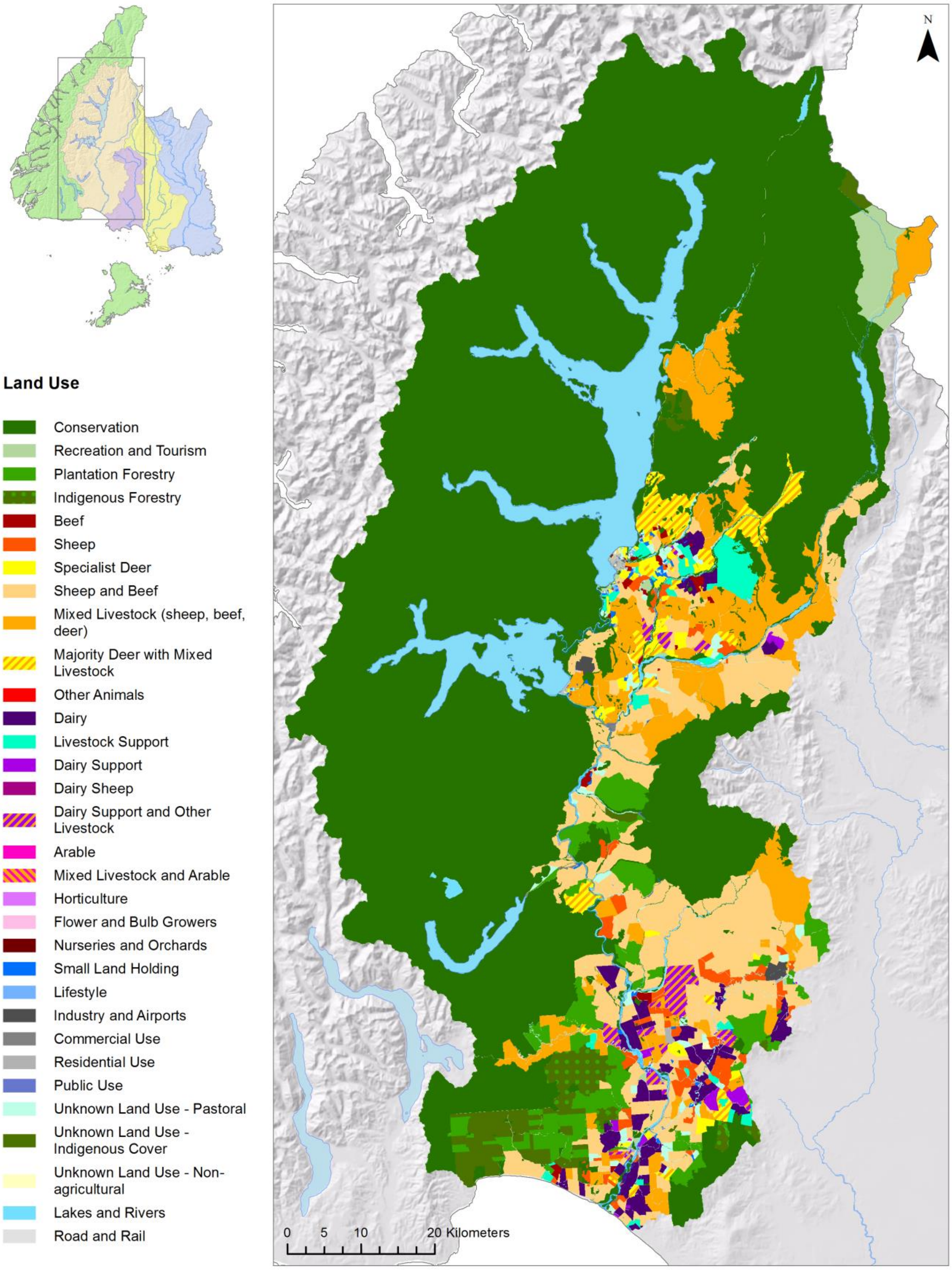

Figure A14: Land use within the Waiau FMU
Source: Southland Land Use Map, Pearson and Couldrey (2016)

1.4.3. Aparima and Pourakino – Jacobs River Estuary

The Aparima FMU covers around 206,700 hectares (6.5% of the region) and is a smaller FMU in comparison with the other FMUs in Southland. Around 168,000 hectares, or 81 percent of the FMU, is developed land and it contains large areas of public conservation land. There is also a large beech forest management area in the Longwood Range (this area is part of the Waitutu Block Settlement Act). The Aparima FMU lies entirely within Southland District and there are around 5,937 residents (2.9 people/km^2). The towns include Otautau, Drummond, Colac Bay and Riverton and have domestic water takes, wastewater and/or stormwater schemes. The agricultural land consists mostly of drystock and dairy properties. Table A3 gives estimates of the extent of land use activities within the Aparima FMU.

Table A3: Agriculture, forestry and urban areas in the Aparima FMU

Land Use	Total land in FMU (ha)	Share of developed land in FMU	Share of total land use in region that is present in this FMU	Number of properties in FMU
Sheep and beef	68,616	40.9%	9.0%	353
Dairy (incl. support)	56,550	33.7%	21.5%	291
Deer	3,529	2.1%	8.1%	20
Arable	4,495	2.7%	19.2%	32
Horticulture	210	0.1%	0.0%	1
Other	6,977	4.2%	-	533
Forestry	23,175	13.8%	24.7%	49
Urban	4,163	2.5%	9.1%	2,802
Total	**167,715**	**100.0%**		**4,080**

Source: Southland Land Use Map, Pearson and Couldrey (2016)

The FMU includes Lake George, the Waimatuku Estuary and Aparima River, and Jacobs River Estuary. Jacobs River estuary is a small base port for commercial fishing vessels and recreational vessels and is highly valued for mahinga kai and recreation. It is also the discharge point for Riverton's stormwater. Whitebaiting is highly valued within this FMU.

Aparima was named after the daughter of the rangatira Hekeia who was bequeathed all of the land that he could see as he stood on a spot at Otaitai, just north of Riverton (Doc, n.d.). A Statutory Acknowledgement applies to the Aparima River and Uruwera (Lake George) and a Tōpuni for the Tākitimu Range.

The mouth of the river was a permanent settlement, with urupā (burial sites) and other archaeological sites nearby. It was also a tauranga waka (landing place) from which sea voyages were made to and from Te Ara a Kiwa, Rakiura and the tītī islands. The river is an important source of mahinga kai, particularly shellfish, tuna (eels) and inanga (whitebait) – an eel weir was built at the narrows where the Pourakino River enters the Aparima. The relationship of the Aparima River to the Tākitimu Hills is an important part of Ngāi Tahu's relationship to the river. Figure A15 shows the distribution of land uses within the Aparima FMU.

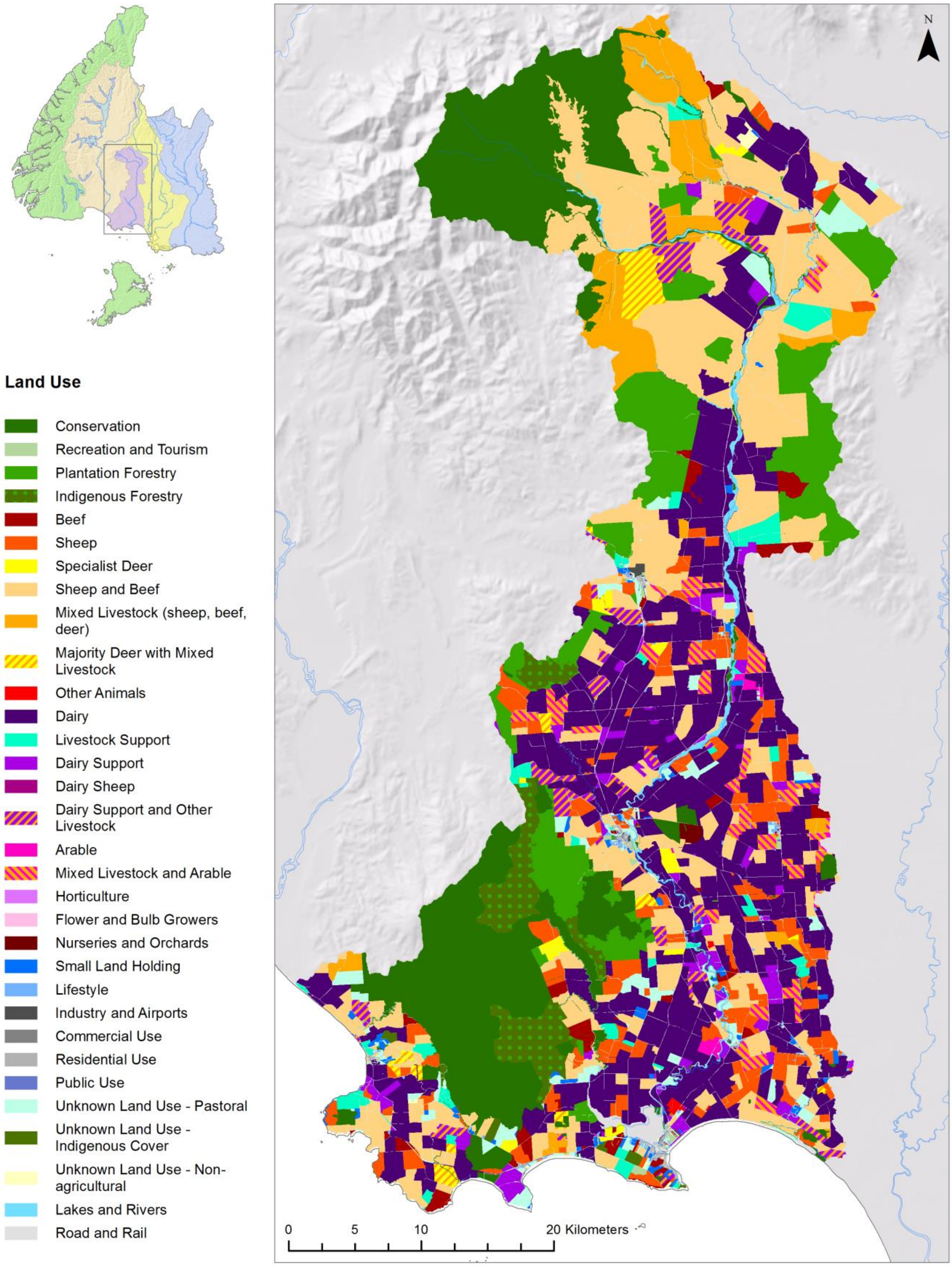

Figure A15: Land use within the Aparima FMU

Source: Southland Land Use Map, Pearson and Couldrey (2016)

1.4.4. Ōreti and Waihopai – New River Estuary

The Ōreti FMU covers around 420,400 hectares (13.1% of the region). Around 330,000 hectares, or 78.5 percent of the FMU, is developed land and there are also large areas of public conservation land. The Ōreti is the only FMU that extends across all three territorial authorities: the Southland District, Invercargill City, and a small part in Gore District. This FMU is by far the most populated in the region, with around 61,264 residents (or 14.6 people/km^2) mostly concentrated in and around Invercargill. Other towns include Lumsden, Browns, Waikaia, Waianiwa, Wallacetown, Winton, and Bluff – most of which have water takes, wastewater and/or stormwater schemes. The agricultural land is primarily dairy farming in the south and a mix of pastoral properties in the north. Table A4 gives estimates of the extent of land use activities within the Ōreti FMU.

Table A4: Agriculture, forestry and urban areas in the Ōreti FMU

Land Use	Total land in FMU (ha)	Share of developed land in FMU	Share of total land use in region that is present in this FMU	Number of properties in FMU
Sheep and beef	152,156	46.1%	20.0%	1,091
Dairy (incl. support)	100,198	30.3%	38.1%	541
Deer	10,538	3.2%	24.3%	94
Arable	6,376	1.9%	27.2%	62
Horticulture	245	0.1%	48.8%	9
Other	23,595	7.1%	-	2,890
Forestry	19,923	6.0%	21.7%	114
Urban	17,221	5.2%	37.5%	25,671
Total	**330,253**	**100.0%**		**30,472**

Source: Southland Land Use Map, Pearson and Couldrey (2016)

Fresh water from the Ōreti ends up in New River Estuary, Bluff Harbour and Awarua Bay, which form part of the RAMSAR[14] Waituna-Awarua Wetland of International Importance. New River Estuary originally covered more than 6,209 hectares but since European settlement an estimated area of 1,652 hectares has been reclaimed and the estuary's current area is 4,557 hectares (roughly 27% of its original extent. The estuary (directly and indirectly) receives Invercargill's wastewater and stormwater schemes and the estuary has been partly reclaimed (roughly 12 km^2). The reclaimed land contains the Invercargill airport, a closed landfill, an industrial zone and farm land. There is a Water Conservation Order (2008) for the Ōreti River, covering 'specific waters' in the Ōreti catchment. The river provides a habitat for brown trout, black-billed gulls and an angling amenity. The direct Māori translation of Ōreti is obscure but may relate to it being a place to snare.

A Statutory Acknowledgement applies to the Ōreti River and Motupōhue (Bluff Hill), as well as a tōpuni for Motupōhue. The Ōreti River forms one of the main pounamu trails from inland Murihiku to the coast. There are many archaeological sites in the upper catchment, including some relating to

[14] The Ramsar Convention (The Convention on Wetlands of International Importance) is the intergovernmental treaty that provides the framework for the conservation and wise use of wetlands and their resources (http://www.ramsar.org/).

stone resources that are amongst the oldest in New Zealand. Figure A16 shows the distribution of land uses within the Ōreti FMU.

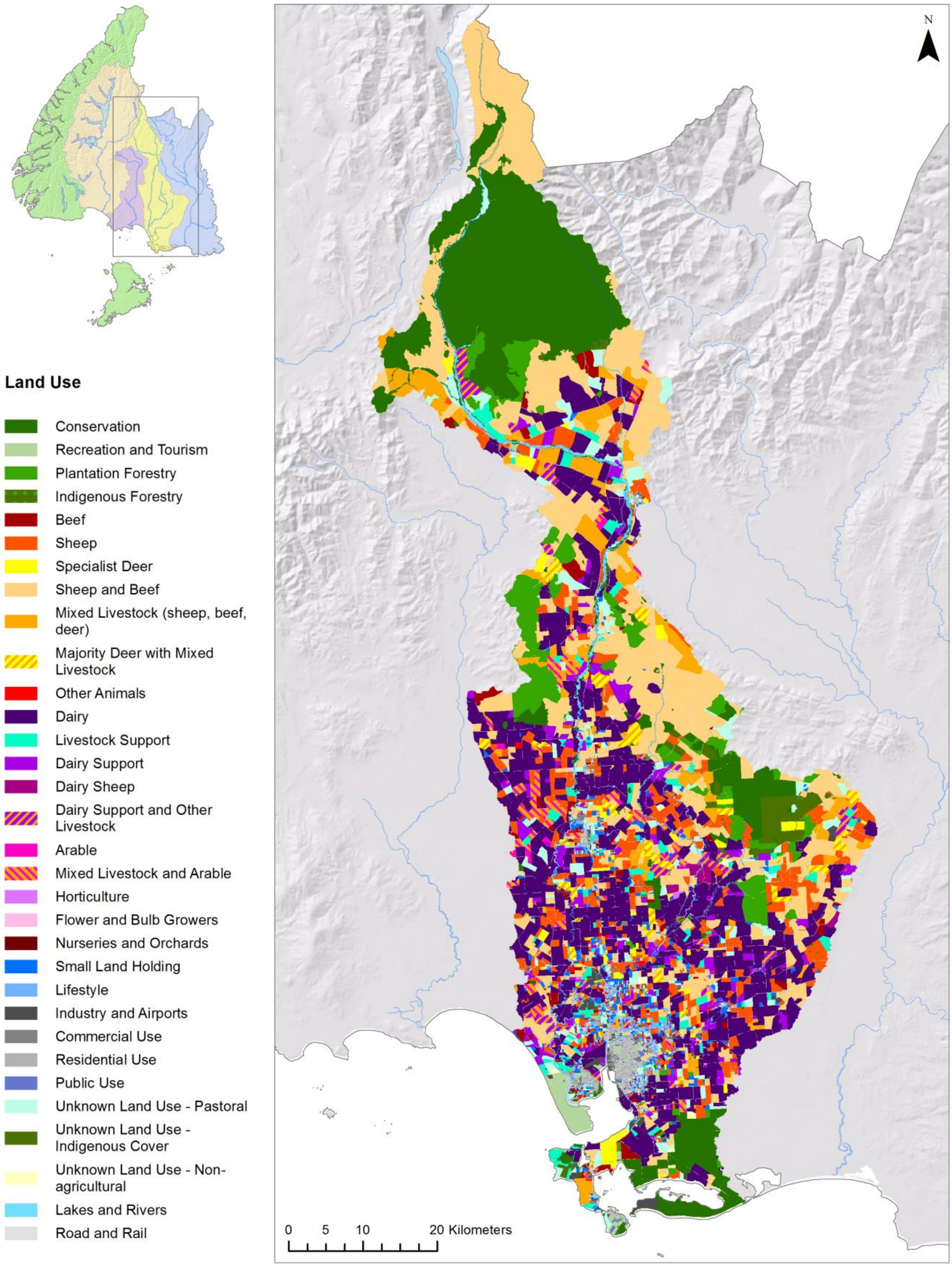

Figure A16: Land use within the Ōreti FMU
Source: Southland Land Use Map, Pearson and Couldrey (2016)

1.4.5. Matāura – Toetoes Harbour

The Matāura FMU covers around 640,000 hectares and it is the second largest developed FMU in Southland. Around 550,500 hectares, or 86 percent of the land, is developed the highest percentage of any FMU in the region) and there are large areas of public conservation land. It is also the second most populated FMU with about 18,035 residents (or 2.8 people/km^2). The FMU lies within Southland and Gore Districts and towns include Edendale, Wyndham, Waikaia, Gore and Matāura with water takes, wastewater and/or stormwater schemes. The FMU has mostly dairy farming on the plains and a mix of drystock properties in the hills. It also includes several large high country stations that straddle the regional boundary with Otago and include Crown Pastoral Lease Land. Table A5 gives estimates of land use activities for the Matāura FMU.

Table A5: Agriculture, forestry and urban areas in the Matāura FMU

Land Use	Total land in FMU (ha)	Share of developed land in FMU	Share of total land use in region that is present in this FMU	Number of properties in FMU
Sheep and beef	392,399	71.3%	51.5%	1,062
Dairy (incl. support)	87,083	15.8%	33.1%	471
Deer	13,294	2.4%	30.7%	35
Arable	12,522	2.3%	53.5%	66
Horticulture	232	0.0%	46.1%	10
Other	16,394	3.0%	-	1,051
Forestry	18,139	3.3%	19.4%	87
Urban	10,397	1.9%	22.6%	6,958
Total	**550,460**	**100.0%**		**9,740**

Source: Southland Land Use Map, Pearson and Couldrey (2016)

Waituna Lagoon is a sub-unit within this FMU and forms part of the RAMSAR Waituna-Awarua Wetland of International Importance. Lake Brunton is a shallow brackish coastal lagoon located in Waipapa Bay. This FMU has a strong whitebaiting community. Freshwater from the Matāura ends up in a number of coastal environments, including Waituna Lagoon, Toetoes Harbour, Haldane Bay, Waikawa Harbour, Lake Brunton and Lake Vincent.

The Māori origin of the name 'Matāura' is unknown but it possibly means reddish, brown, or glowing face. A whaling station was established at the village of Toitois, now called Fortrose, on the edge of the estuary at the mouth of the Matāura River. The estuary was dubbed 'Toetoes Place' by the whalers and Toetoe was the name later given to the estuary/harbour and the bay.

There is a Water Conservation Order (1997) for the Matāura River to protect fisheries and angling amenity features. Statutory acknowledgements recognise the significance of the Matāura River and Waituna Wetland. The Matāura River is linked to several important Ngāti Māmoe and Ngāi Tahu tūpuna. A freshwater mātaitai reserve recognises the importance of the river for customary food gathering. The Matāura Falls is an important source of kanakana and inanga (whitebait) and a feature of the cultural landscape. Toetoe estuary is a particularly important location for customary food gathering. Figure A17 shows the distribution of land uses within the Matāura FMU.

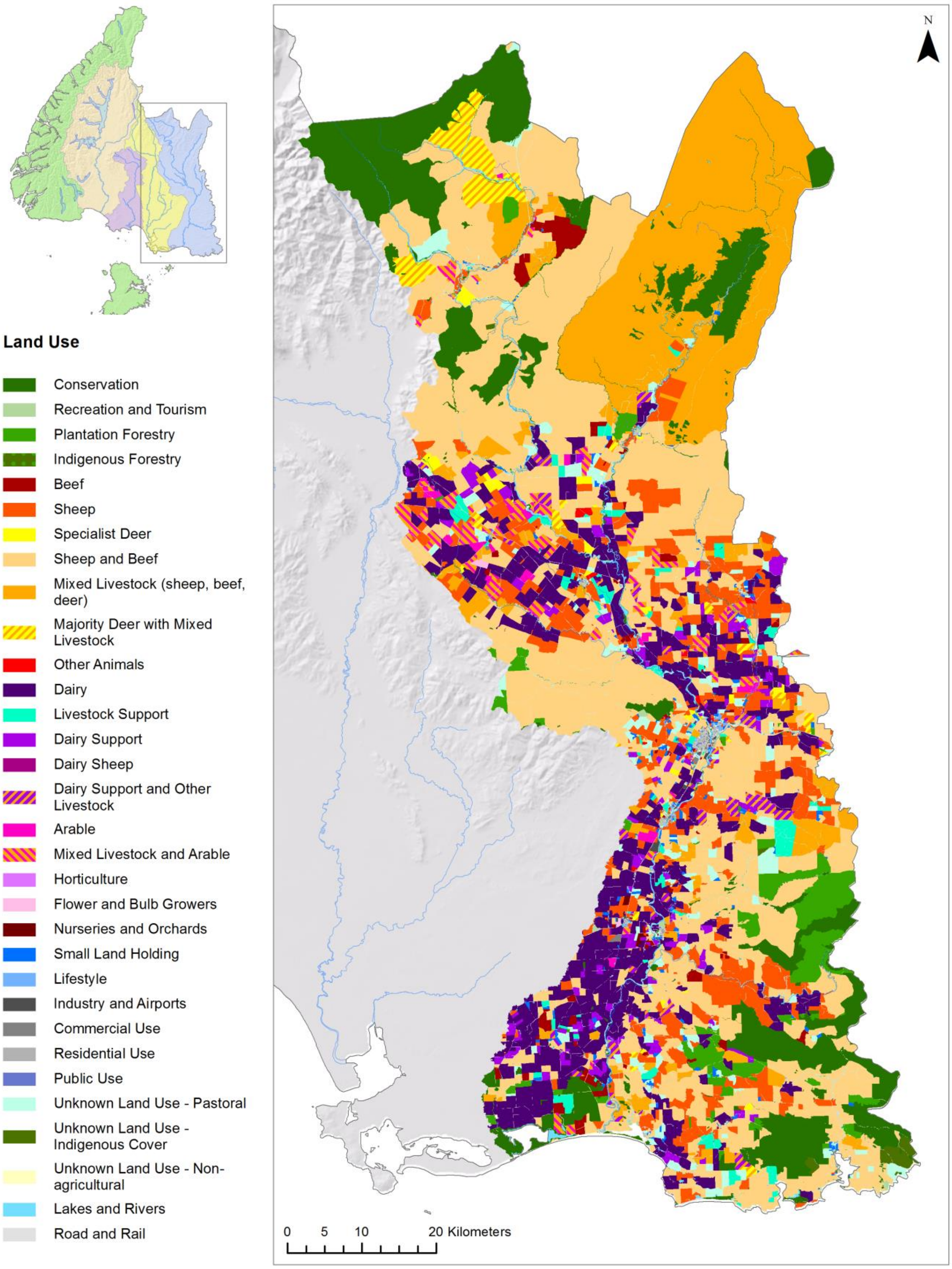

Figure A17: Land use within the Matāura FMU
Source: Southland Land Use Map, Pearson and Couldrey (2016)

2. Climate and Soils

Environmental conditions influence how and where agriculture and forestry occur across Southland, with climate, topography and soils being both inputs into, and constraints on, their production systems. In Southland pasture growth starts later than further north; soils in some places are often wetter for longer and restrict activities such as crop cultivation than elsewhere; and in summer there is higher available soil water (or moisture) and less risk of drought.

Agricultural and forestry production systems have either adapted to fit their environmental conditions (e.g. a higher ratio of sheep to beef cattle or the wintering of heavier stock off paddocks) or steps have been taken to alter these conditions that are not as necessary in other regions. The most obvious step was the installation of extensive tile and mole drainage networks where there was marginal land or wetlands. Some of the steps taken to alter environmental conditions can result in increased losses of by-products such as surplus nutrients.

For agriculture in particular, climate, soils and topography (along with management) control the amount of nutrients lost. Consequently, nutrient losses from a farming activity can require more management (or mitigations) under some environmental conditions than others. Rainfall (quantity, altitude, and proximity to the coast) and soils are used, along with other factors, in physiographics[15] to explain some of the spatial variation in the quality of fresh water. In other words, the location (or context) of a farming activity is important.

This section describes Southland's climate and soils because of the importance of these factors in the development of agriculture and forestry, and their nutrients losses. Rainfall and soil drainage are particularly relevant to this research because they were used to develop broad categories for selecting the individual pastoral (dairy and drystock) farms for case studies within each FMU. Possible climate change scenarios are also outlined as it will influence both agriculture and forestry, and nutrient losses in the future. It is followed by sections briefly describing land use class capability and Environment Southland's physiographic zones.

2.1. Climate

Southland's climate is characterised by westerly airflows, a general eastwards progression of weather systems, and lower temperatures compared to regions further north. The climate has a major influence on the agriculture and forestry sectors and on fresh water, the volume and timing of by-products lost from these sectors, and also the mitigation options available to reduce these losses.

The interaction between the prevailing weather conditions and the mountainous terrain creates variation within the region. The Fiordland mountain ranges (e.g. Murchison, Darran, Cameron) act as a barrier to westerly airflows. Consequently, the area experiences extremely high rainfall as the maritime air rises and condenses. Areas to the east, especially north of the Hokonui Hills, receive relatively lower rainfall, with inland valleys and basins more sheltered from the strong westerly winds prevalent along the region's south coast.

[15] For general information on the physiographic zones refer to factsheets on Environment Southland's website and for technical information refer to the Physiographics of Southland - Part 1 - Delineation of key drivers of regional hydrochemistry and water quality (Rissmann, et al., 2016).

2.1.1. Temperature

Air temperatures show a small annual range in Southland, with July usually being the coldest month and January the warmest. The average annual variation in daily temperature range (T_{max}-T_{min}) is about 9°C in Invercargill and Gore, increasing to around 10.5°C in Lumsden and Manapōuri (Macara, 2013). Temperature variation tends to be less in low elevation coastal areas because of the sea's moderating effect.

Winters in Southland can be severe by New Zealand standards. The mean maximum temperature in Invercargill in July is just 9.5°C, compared with 11.3°C in Christchurch and 14.7°C in Auckland (Grant, Updated 2015b). Frosts occur relatively frequently across most of Southland, particularly in the inland basins. Between the years of 1981 and 2010, an average of 104 ground frosts per year was recorded in Invercargill.

In addition to frost, snowfalls also occur occasionally in lower elevation areas of Southland, usually settling for a day or two. Invercargill, on average experiences five days of snow per year (Macara, 2013). At higher elevations seasonal snowfields develop over winter. This accumulation of snow influences discharge in the major river systems with stable base flows during the winter months, followed by an extended period of elevated flows during the spring and early summer melt.

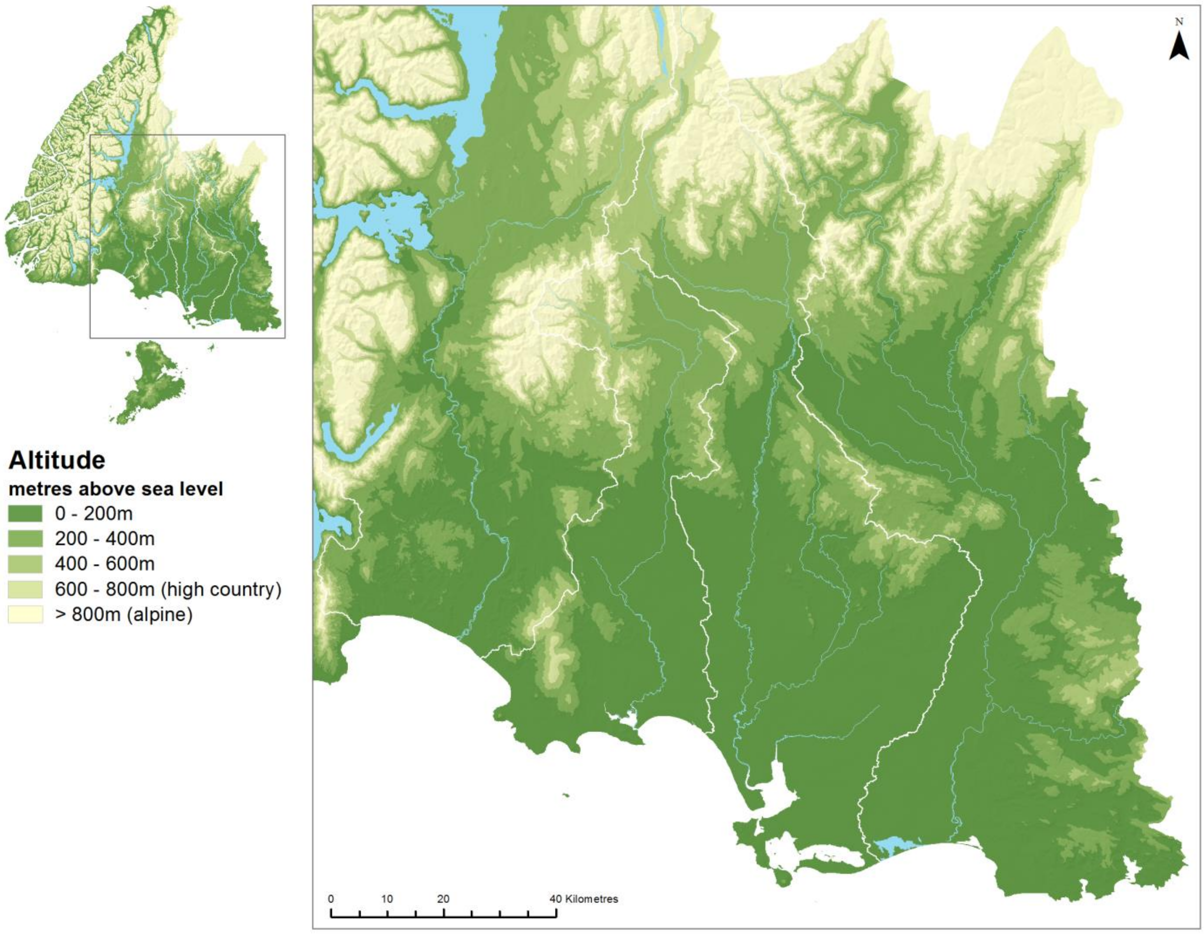

Figure A18: Altitude in metres above sea level
Note: Greater than 600 metres above sea level is identified as 'High Country'. Greater than 800 metres is identified as 'Alpine'.

These conditions can be a limiting factor on farms. In Southland 600 m (and above) in altitude corresponds to an annual average temperature of 8°C. Agricultural land higher than 600m is considered 'high country' and is usually extensively farmed. This altitude also limits the growth and establishment of improved pastures and exotic forest – Pinus radiata (radiata pine) and Douglas fir (Harrison & Meason, 2015).

Areas between 800 and 2,740 metres above sea level are considered 'Alpine'. They correspond to high rainfall (4,240 mm mean annual) and snow pack accumulation, shallow, well-drained soils, and moderately steep to very steep slopes. 800 metres above sea level is the natural boundary of the treeline, above which the dominant land covers are tussocks, scrub and alpine plants as well as bare rock and scree slopes. Figure A18 (above) shows developed land in lower and higher altitude bands.

Average 9am soil temperatures (at 10 cm depth) in Southland exhibit strong seasonal variation from a maximum of 14 to 16°C during the summer months to less than 5°C during June and July (Macara, 2013). In coastal areas soil temperatures are typically slightly higher in winter and lower in summer compared to inland areas.

Soil and air temperatures exert a strong influence on dry matter production, with pasture growth rates declining across Southland from May through to August. Continuation of below normal air and soil temperatures through spring can result in seasonal feed deficits that can reduce stock condition and reproductive success.

Image A5: Sheep farm in Northern Matāura
Source: Emma Moran

2.1.2. Sunshine Hours and Growing Degree Days

Southland receives relatively low annual sunshine hours compared to the rest of New Zealand. Invercargill has an average of 1,682 sunshine hours each year, compared with 2,003 hours in Auckland, and 2,142 in Christchurch (Grant, Updated 2015b). South-western areas of Southland are particularly cloudy receiving less than 1,300 hours of bright sunshine annually.

The number of sunshine hours has implications for 'growing degree days' which is a measure of heat accumulation (in degrees Celsius) above a certain base temperature over time. In other words, it is how much warmth there is available for a plant's biological growth over a growing season. This information helps farmers and growers predict plant growth and stock development. In Southland, farmers grow forage crops and conserve pasture as hay / baleage / silage to transfer high-quality feed grown during periods of high plant growth to periods of low growth.

Using a base of 5^{o}C, growing degree days in Southland range from around 1,700 per year in Manapōuri to around 1,825 in Gore, Lumsden and Invercargill. By comparison, growing degree days (using the same base) typically exceed 3,000 per year across warmer parts of the North Island. As a result, the growing season starts late in Southland (typically in September), and lasts well into autumn. The start of the growing season is around the same time as lambing, but 4-6 weeks after calving, which is well under way by mid-August. As a result, the pasture and crop growing season is much shorter in Southland compared to areas further north, putting pressure on Southland farmers to grow their products quickly.

Image A6: Making silage on a dairy farm near Ryall Bush
Source: Lloyd McCallum

2.1.3. Rainfall

Interaction between the prevailing westerly airflows and the mountainous terrain results in considerable variability in rainfall across Southland. This spatial variability occurs within the context of wider patterns of temporal variability, in particular the El Niño Southern Oscillation, and other factors such as sea surface temperature. Heavy or prolonged rainfall flushes away in-stream accumulations of periphyton (slime algae). The mountains of Fiordland form a partial barrier to the prevailing westerlies and consequently receive extremely high rainfall totals. To the east, the topography is relatively complex with large mountain ranges separated by basins, river valleys and alluvial plains. Average precipitation on hills and ranges increases with elevation, but considerable spill-over and rain-shadow effects can occur in inland basins. In general, the inland valleys of Northern Southland are relatively dry, receiving between 800 and 1,000 mm of rainfall per year.

The southern coastline's exposed location and channelling of air through Foveaux Strait means that limited shelter is afforded from the strong westerlies and rainfall tends to be higher and more frequent than further inland. Mean annual rainfall recorded in Southland ranges from around 700 mm in the Riversdale area (Matāura) to 6,500 mm/year at Milford Sound (Fiordland). Figure A19 shows the rainfall map used in OVERSEER for developed land in Southland.

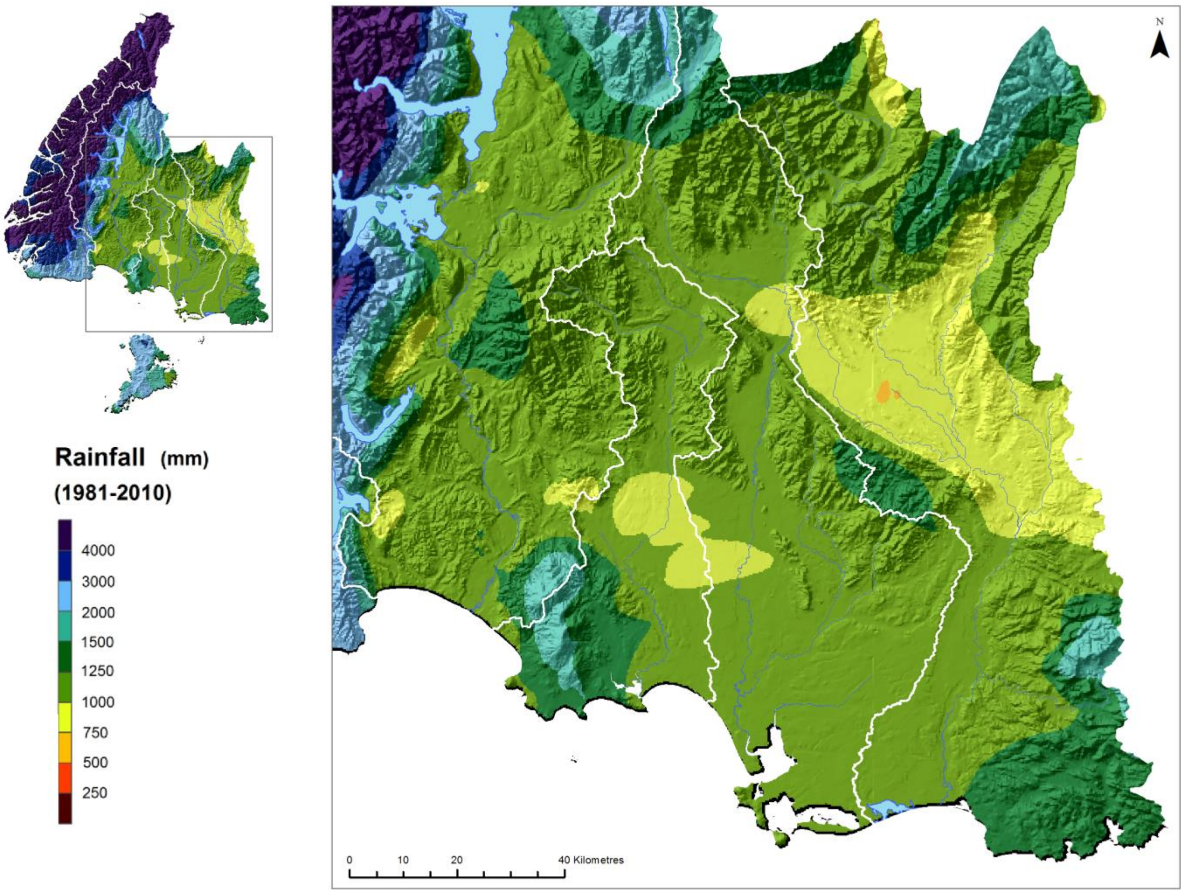

Figure A19: OVERSEER rainfall map for developed land in Southland 1981-2010
Source: NIWA
Note: The white lines on the map indicate the FMU boundaries discussed in Section 1.4.

Compared to the rest of New Zealand, variation of rain days (>0.1 mm/day) and wet days (>1 mm/day) between seasons in Southland is relatively small. Monthly rainfall totals are generally highest in late spring and early summer (October to January), influenced in part by prevailing westerly air flows. Rainfall patterns and snow-melt from alpine headwaters mean that monthly river flows are generally highest during spring. Extended periods of rainfall can have implications both for farmers' ability to get out 'on the paddock' after winter and to manage their nutrient losses.

More southerly air flows during the winter months bring drier air and lower rainfall (July is generally the driest month). Coastal areas of Southland generally experience frequent rainfall with between 140 and 160 wet days per year (greater than 1 mm / day) occurring over much of the Southland Plains. Rainfall frequency increases to more than 200 wet days per year along the south coast and decreases to less than 130 days per year north of the Hokonui Hills.

Southland also experiences episodes of high rainfall, typically from the passage of westerly fronts during the summer and autumn months. During such events 24-hour rainfall totals can be more than 25 to 50 mm over a lot of the region, resulting in surface flooding and high flows in the major rivers and streams. Thunderstorms also occur in inland areas during the summer months, resulting in localised, intensive rainfall. Depending on land management practices, episodes of heavy rainfall increase the potential for elevated losses of sediment and nutrients from pastoral agriculture and forest harvesting operations.

Calculated evapotranspiration[16] (total potential evapotranspiration or PET) is relatively uniform across Southland, ranging from between 720 and 770 mm per year. There is seasonal variability with monthly PET values ranging from between 120 and 130 mm/month in summer (Dec/January) to less than 15 mm/month in winter (June/July). By comparison, PET values per year over much of central and northern New Zealand range from between 900 and 1,100 mm, with monthly values often exceeding 150 mm during summer (Macara, 2013).

2.1.4. Soil Moisture

Soil moisture typically is at or near field capacity[17] for extended periods of time over much of Southland, particularly on heavier soils in central, eastern and coastal parts. Soil moisture in these areas may remain elevated for more than 150 days from late autumn through to spring when soil temperatures are low. These conditions limit nutrient uptake for plant growth (and so agricultural production) and also land management activities. They also increase the potential for losses of nutrients, sediment and microbes from agriculture via overland flow, artificial drainage and recharge to underlying aquifers. Extended periods of elevated soil moisture levels impact farming operations, especially when wetter and/or colder than average conditions arrive early or persist through spring.

To manage feed supplies and avoid damage to soil structure from intensive winter grazing on wet soils, the wintering of stock off-farm is a common practice in central, southern and western Southland. This practice usually involves transport of stock to grazing located on areas of lighter,

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[16] Evapotranspiration is a process where water is released to the atmosphere via a combination of direct evaporation from the soil surface and transpiration from plant leaves (McLaren & Cameron, 1996).

[17] Field Capacity is the state of the soil after rapid drainage has effectively ceased and the soil water content has become relatively stable (McLaren & Cameron, 1996).

free draining alluvial soils in inland areas over the winter period. The use of housed wintering systems has also increased on dairy farms in recent years. Extended periods of elevated soil moisture also require the use of storage to manage effluent application to help minimise nutrient losses when soils are wet.

In general, Southland experiences a temperate climate with rainfall evenly distributed throughout the year and modest evapotranspiration rates. Parts of the region, particularly northern Southland and the Te Anau Basin, can experience periods of prolonged below average rainfall resulting in considerable soil moisture deficits. These drought conditions are usually of limited duration, and tend to affect only on part of the plant growing season. Typically, summer drought events impact on stock finishing and peak milk solids production, whereas drought conditions in autumn tend to have greater impact on winter feed supplies and reproductive health. Recent years have seen expansion of pasture irrigation in inland basins to maintain production during dry periods. In 2017 there were 134 permits for consumptive water takes relating to crop and pasture irrigation in Southland.

For real-time soil moisture and soil temperature conditions see Environment Southland's online map service (Environment Southland, n.d.)[18]. Soil moisture and temperature (at 10 cm) are recorded at 20 sites across Southland on a variety of soil types. These sites can be used as reference sites for land users to guide whether soils conditions are suitable for effluent disposal, fertiliser application, and irrigation scheduling at a district scale.

2.1.5. Wind

Image A7: Wind wrought trees near Fortrose
Source: David Moate

[18] http://gis.es.govt.nz/index.aspx?app=soil-moisture

The exposed location and channelling of air through Foveaux Strait mean the southern coast experiences a high frequency of strong westerly winds. Invercargill is New Zealand's second windiest city, after Wellington, recording an average annual wind speed of 17 km/hour with an average of 48 days of strong winds (daily mean wind speed >30 km/hr) per year. Average wind speeds decline in inland areas reflecting the sheltering effects of the surrounding topography with Gore, Lumsden and Manapōuri all recording an average of less than 15 days of strong winds per year. The frequency of strong wind gusts (>60 km/hr) also decreases in inland areas compared to the south coast. Windy days in Southland tend to be seasonal, with between 30 percent and 40 percent of strong winds in spring and the lowest frequency of strong winds in winter (Macara, 2013).

High wind, particularly in inland areas, may worsen seasonal soil moisture deficits and result in soil erosion. The reality of wind erosion was bought to public notice in 1961 when gale-force northerly winds blew tons of topsoil off newly ploughed paddocks between Te Anau and Mossburn (Poole, 1990). The result was a dust cloud visible from Invercargill (roughly 100km away) and the Mossburn Post Office reported dust left lying two feet thick in places. Strong wind gusts can also result in windthrow (the uprooting or throwing over of trees) in plantation forests.

2.1.6. Climate Change

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The current climatic conditions are changing – there are projected increases in temperature, overall precipitation (particularly over autumn and spring), and the frequency of dry days (especially in summer). These changing conditions will put biodiversity and the health of ecosystems under pressure. Climate change is highlighted because of its relevance for the future outlook of both agriculture and forestry, and for its potential effects on nutrient losses from agriculture.

Projections of climate change depend on future levels of greenhouse gas emissions, which are uncertain. NIWA has simulated the four main global emission scenarios[19] for Southland up to 2120. These emission scenarios used different carbon emission levels (from low to high) to simulate changes in temperature and precipitation (rain and snow only[20]). The predicted changes were calculated for the two twenty year periods from 2031 to 2050 (referred to as 2040) and from 2081 to 2100 (referred to as 2090).

In Southland, the predicted changes in average temperatures tend to increase under each of the four emission scenarios. Compared to 1995, temperatures are likely to increase by between +0.6°C and +0.9°C, and between +0.7°C and +2.8°C by 2090. Southland is expected to become warmer, particularly during autumn and winter, and least in spring. Warming is greatest in autumn, and least in spring. By the end of the century, it is predicted that there will be up to 16 extra days a year

[19] NIWA used a suite of regional climate models to simulate the emission scenarios, which technically are 'radiative forcing' scenarios (known as "Representation Concentration Pathways"). Radiative forcing is the change in energy in the atmosphere as a result of greenhouse gas emissions. The four emission scenarios tested were a low emissions scenario, which involved the removal of some carbon dioxide (CO2) (RCP2.6), two 'business as usual' scenarios with emissions stabilising in different time periods (RCP4.5 and RCP6.0), and a high emissions scenario (RCP8.5). The predicted changes across the four scenarios give a range of results that is then compared to what the climate was like from 1986 to 2005 (referred to as 1995).

[20] Climate change models do not have the complexity required to predict hail as a component of the precipitation.

where maximum temperatures are above 26°C, with fewer frosts and snow days experienced. Less winter snowfall and earlier spring melt may cause marked changes in the annual cycle of river flow.

A general increase of precipitation in Southland is highly likely this century. Unlike temperature, the predicted changes in average precipitation tend not to grow across the four emission scenarios. Compared to 1995, precipitation is likely to increase by between +2 and +4 percent by 2040, and +6 and +9 percent by 2090. Southland is expected to become wetter, particularly during winter and spring. The most common pattern of annual precipitation change in Southland is for an increase in the east-west gradient, peaking over the Southern Alps ridge. The frequency of dry days (where precipitation is below 1 mm/day) is also likely to increase, although in Fiordland it is likely to decrease, reflecting the expected increase in the west-east gradient. These effects are likely to change the current seasonal precipitation patterns in the region.

2.2. Soils

Soils are essential for agricultural and forestry production systems and a non-renewable resource because they take centuries to develop. Soil properties reflect the age, parent materials, climate, topography, and biological activity (microbes and vegetation) when the soil was formed (Molloy & Christie, 1998). They are key factors in determining what agricultural uses are possible, where these uses occur in the landscape, and how substances are lost from them to water. Soil properties influence what happens in the soil zone, how water moves, and the loss of nutrients. Nutrients are either dissolved in water or carried by water over the land surface. The same activity on two different soil types can have vastly different outcomes for water quality. Understanding soils and the role of the soil zone is critical to the choice of effective mitigations.

Information on soils and their management is needed to assess how nutrients are transported and ultimately lost from a production system, and this information is used in OVERSEER. Many of the limiting properties of the soils in Southland have been overcome with human intervention. The largest modification to soils has been improving soil drainage through the addition of tile and mole-pipe drains. The development of industry specific farming practices and forestry in Southland is closely linked to the capabilities of the soil. This section covers the main soil orders (identified using the New Zealand Soil Classification) present in Southland and their properties, and the link between soils and water quality. Appendix 1 contains information on the New Zealand Soil Classification (Hewitt, 1993; Hewitt, 2010), the soil maps available for Southland, and a table of Southland's soils by series (local name), New Zealand Soil Classification, extent (hectares) and drainage class[21].

2.2.1. Southland Soils

The soils over much of the agricultural land of Southland are moderately deep to deep soils. The distribution of the soils, along with the climate, has driven agricultural development in Southland.

[21] An interactive map of soils in the region can be found at http://gis.es.govt.nz using the TopoClimate soil maps. This can be used to get soil maps suitable for farm scale (± 100m) along with detailed report cards for each soil series.

Figure A20 shows the depth of soils across Southland. Overtime, the loss of sediment will affect soil depth and potentially reduce the productivity of the land.

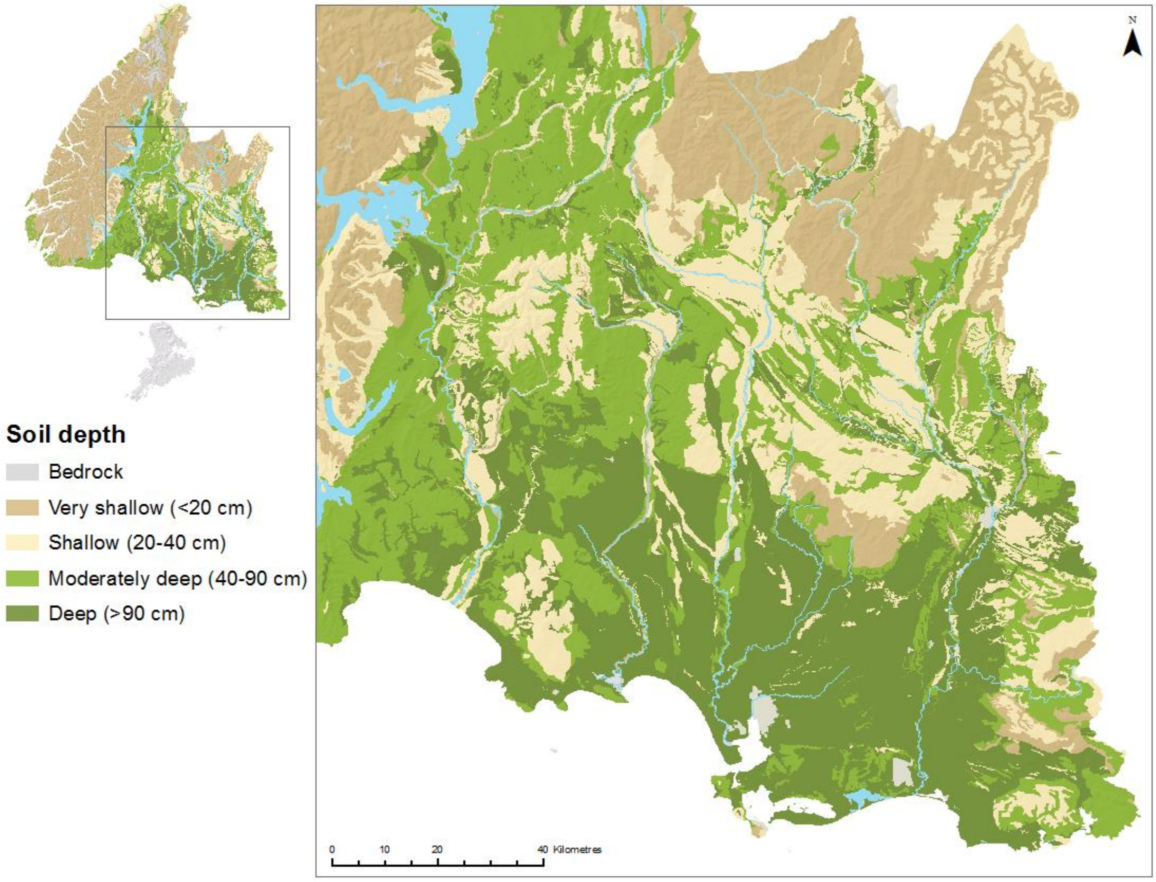

Figure A20: Depth of Southland soils
Source: Soil data from Topoclimate South (Crops for Southland, 2001), Land Resource Inventory (DSIR, 1968) and Wallace County (O'Byrne, 1986).

Overall, eleven New Zealand Soil Classification (NZSC) orders have been identified in Southland, of which six soil orders occur on land predominantly used for agriculture and forestry. The range in soil orders is similar to other regions within the South Island. This section discusses these soil orders, highlighting the differences in formation, properties (especially soil drainage), limitations and management (artificial drainage) of the resulting soils. Figure A21 shows the known distribution of the eleven soil orders across Southland.

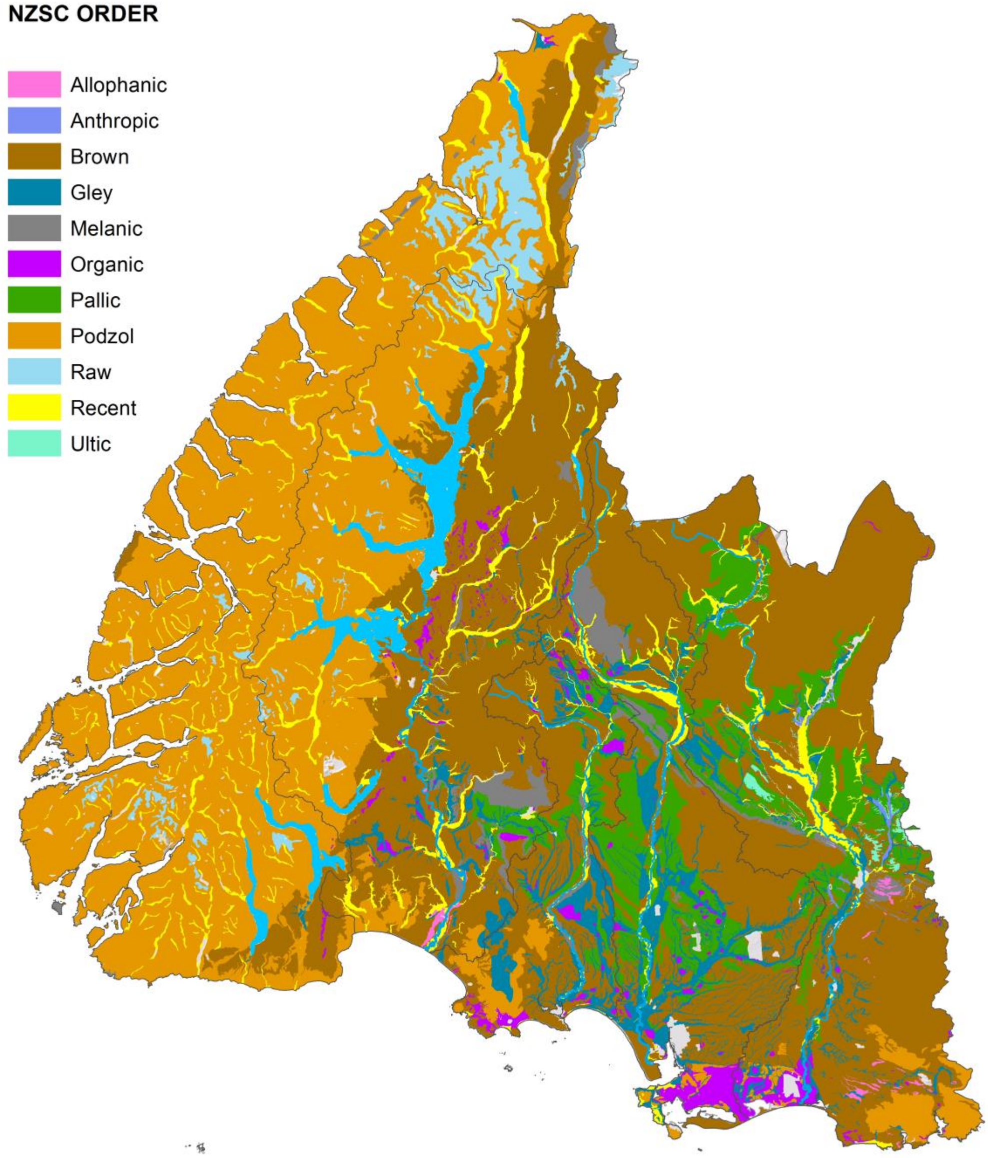

Figure A21: Distribution of New Zealand Soil Classification Order in Southland
Source: Soil data from Topoclimate South (Crops for Southland, 2001), Land Resource Inventory (DSIR, 1968) and Wallace County (O'Byrne, 1986).

Brown Soils

The most extensive soils within the developed land in Southland are Brown soils. They cover an area of around 750,000 hectares of the agricultural and plantation forestland area (roughly 58%), across the hills and higher alluvial terraces of Northern and Central Southland and the Catlins. Brown soils typically have dark-grey brown topsoils over brown or yellow-brown subsoils (Hewitt, 2010) and occur where droughts and water-logging are uncommon. These soils tend to be well-drained, have a deep rooting depth, high water-holding capacity, and well developed structures and silty textures. Despite these general characteristics, in many areas in Southland the fine textured subsoils in Brown soils are compact enough to restrict drainage through the soil profile, resulting in seasonal waterlogging and the use of artificial drainage (typically mole and tile drains) to drain excess soil moisture in low-lying areas. Historically, many low-lying areas with Brown soils formed seasonal wetlands, resulting in an accumulation of a lot of organic matter in the topsoil. Over 80 identified Southland soils are classified as Brown Soils by Topoclimate South Soil Mapping Project (2001).

Pallic Soils

Pallic soils are the second most extensive soil order in Southland, covering 191,830 hectares of land used for agriculture and plantation forestry (approximately 15%). Pallic soils are common in the drier landscape of Northern Plains and are also found across the lowland Central Plains area. These soils have pale coloured sub-soils, because of the low content of iron oxides, a weak structure and high bulk density (Hewitt, 2010), and are often dry in summer and wet in winter. The soil textures are typically heavy silt loams grading with depth to silty clays with a 'fragipan' (denser, less permeable layer) at 45-90 cm depth which severely restricts drainage (forming Perch-gley Pallic soils). Artificial drainage is required to make these soils useable for agriculture. In Southland, there are 21 soils classified within the Pallic soil order by Topoclimate South Soil Mapping Project (2001).

Gley Soils

Gley soils, along with Organic soils (mentioned later), represent the original extent of New Zealand's wetlands (Hewitt, 2010). In Southland, they cover an area of 143,060 hectares of land used for agriculture and plantation forestry, or roughly 5.4 percent. They occur in low-lying parts of the landscape, typically on the flood plains of rivers and streams across the region. The process of gleying occurs when soils become anaerobic[22] because of periodic waterlogging, caused by a high water table or impeded drainage within the soil profile (a perched water table). These conditions produce a light grey/olive/blue-green sub-soil that is usually "mottled" with rusty reddish-brown (iron), black (manganese), or yellow (aluminium) spots or streaks of colour. The soil texture is commonly silty clay to silt loam textures, with high organic matter content and are usually stoneless. As with the Pallic Soils, artificial drainage is required for agriculture. In Southland, 25 soils are classified as Gley soils by Topoclimate South Soil Mapping Project (2001).

Recent Soils

Recent soils are typically coarse-grained, highly permeable, have a low water holding capacity, and low soil organic carbon content. In the Southland, Recent soils cover an area of around 70,040 hectares of land used for agriculture and plantation forestry (or 5.5%) and are located on alluvial floodplains near the main Southland rivers, Matāura, Ōreti, Aparima, and Waiau. The soils are formed in gravelly alluvium derived from greywacke and schist rocks. They are typically free-draining with a silty to sandy texture, with limited rooting depth and soil water holding capacity because of the gravels. Topoclimate South Soil Mapping Project (2001) has classified 14 soils in Southland as Recent soils.

[22] An absence of free oxygen.

Melanic Soils

Other minor Soil Orders in Southland are Melanic and Organic soils. Melanic soils are also found on the Southland Plains, formed in mixed loess and fine colluvium from limestone and calcareous siltstone. They have black or dark grey topsoils that are well structured overlying lime rich subsoils, which makes these soils naturally fertile (Hewitt, 2010). In Southland, Melanic soils cover an area of 42,660 hectares or 3.3 percent of land used for agriculture and plantation forestry. Soil textures are generally silty to clayey, varying according to the amount of loess in the soil, and are typically well-drained with a moderate water holding capacity. Topoclimate South Soil Mapping Project (2001) has classified nine soils in Southland as Melanic soils.

Organic Soils

Organic soils in Southland are formed on peat and cover an area of 30,675 hectares (2.4%) of land used for agriculture in the Southland lowlands. They typically have very poor drainage, very low bulk densities (loose) and are extremely acidic, which restricts their use for most crops. These soils are well suited to producing blueberries. Topoclimate South Soil Mapping Project (2001) has classified five soils in Southland as Organic soils.

Podzol Soils

The seventh soil order, Podzol soils (generally related to accumulated leaf litter overlying silica-rich mineral materials) typically forms in high rainfall environments. Podzol soils cover 43 percent of the whole Southland region (not just agricultural land), and make up a large extent of Fiordland and Catlins to the east, but are a relatively small proportion of the agricultural areas in Southland.

2.2.2. Soil and Water Quality

Water quality in Southland is strongly linked to how water interacts with the soil zone (Rissmann, et al., 2016). The pathway that water takes either over or through the soil zone influences water's geochemical composition, as substances are dissolved in and/or transported by water. The ability of water to move through the soil depends on soil properties, most importantly soil structure and drainage. Topography is an important factor in determining the proportion flowing over the land as opposed to through the soil zone. The main pathways for substances lost from agriculture and forestry are deep drainage, bypass flow, lateral flow, artificial drainage and overland flow (surface runoff). Figure A22 shows the pathways for nitrogen, phosphorus, sediment and microbes.

On rolling to steep land, water is mostly transported over the soil as lateral flows and/or overland flow. The soil zone has minimal contact with water moving laterally over the soil surface but substances such as nutrients, sediment and microbes are picked up from the land surface and quickly transported to water bodies following high or prolonged rainfall (particularly during late autumn and winter). Overland flow can occur when the soil is saturated and unable to hold more water or when the intensity of the rain event exceeds the infiltration capacity of the soil. It most commonly occurs on shallow soils, sloping land, wet soils or where there has been structural damage to the soils restricting water infiltration. Intensive land use activities, such as the winter grazing of stock on forage crops, occurring on these shallow sloping soils quickly overwhelm the capacity of the soil to absorb nutrients and any lateral flow is likely to be high in nitrogen as well as phosphorus.

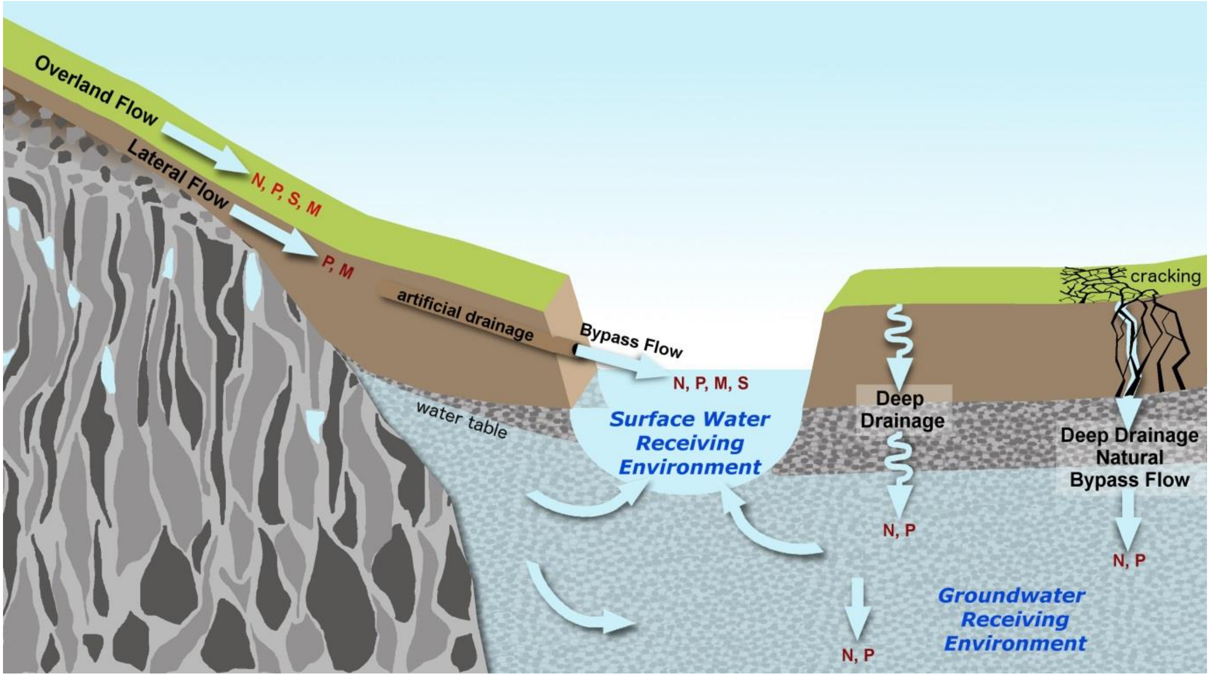

Figure A22: Pathways for nitrogen (N), phosphorus (P), microbes (M) and sediment (S) from the soil zone
Source: Physiographics of Southland, 2016.

Flat and undulating land on the Southland Plains and inland basins both typically have fine-textured soils and slowly permeable subsoils, resulting in imperfectly drained or poorly drained soils. These areas represent the extent of where there were wetlands historically. In many of these areas, the water table is shallow (less than one metre in wetter seasons) and the soils generally contain a lot of organic matter. This combination of factors reduces the risk of nitrogen loss by deep drainage into underlying aquifers, as nitrogen is converted to nitrogen gas and released into the atmosphere (through denitrification).

By contrast, where Brown and Recent soils (well-drained and moderately well-drained soils) are found with the shallow water table there is an increased risk of nitrogen loss in deep drainage through the soil. In areas where gravel or stony well-drained soils are found, the risk of nitrogen loss is very high. These areas are often connected with shallow soils (e.g. Waimea Plains, Te Anau Basin), along current or historic river channels (alluvial parent materials). Figure A23 shows the dominant drainage classes of Southland soils and Table A6 gives soil drainage class by Freshwater Management Unit.

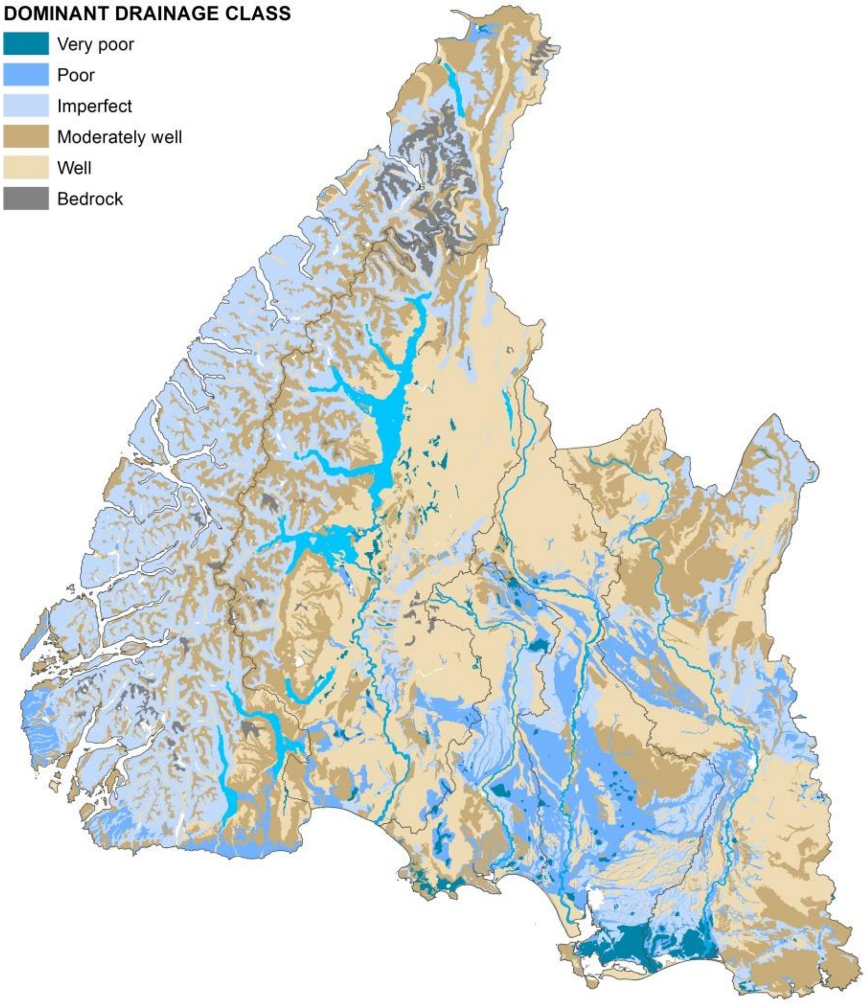

Figure A23: Dominant drainage classes of Southland soils
Source: Topoclimate South (2001) and Land Resource Inventory (DSIR, 1968).

Table A6: Soil drainage by FMU

FMU	Poorly drained (Drainage Class 1-3)		Well-drained (Drainage Class 4-5)	
	Area (ha)	Share of FMU	Area (ha)	Share of FMU
Fiordland (not incl. islands)	489,852	60%	331,927	40%
Waiau	179,827	23%	441,277	56%
Aparima	88,729	43%	117,036	57%
Ōreti	189,872	47%	217,759	53%
Matāura	194,746	31%	441,277	69%

Source: Topoclimate South (2001) and Land Resource Inventory (DSIR, 1968).

Deep drainage is the pathway for recharging groundwater aquifers. Nutrients transported by deep drainage accumulate in the groundwater increasing the concentration and reducing the future use of the water. For many rural residents, groundwater is the source of drinking water, stock water and used in the farming operation. The water quality and supply of this resource is critical to their existence on the land.

To overcome poorly drained soils, extensive drainage systems and management practices have been introduced over the years, which move water laterally through artificial drainage systems rather than these areas being saturated and unsuitable for agricultural use. Artificial drainage, such as tile and mole drains, has implications for water quality because it gives poorly drained soils similar drainage characteristics as well-drained soils. Artificially drained soils have far less ability to remove nitrogen and other substances from water flowing through the soil than would otherwise be the case, as most of the water bypasses the soil zone. Figure A24 shows areas where artificial drainage likely occurs in Southland (Pearson, 2015).

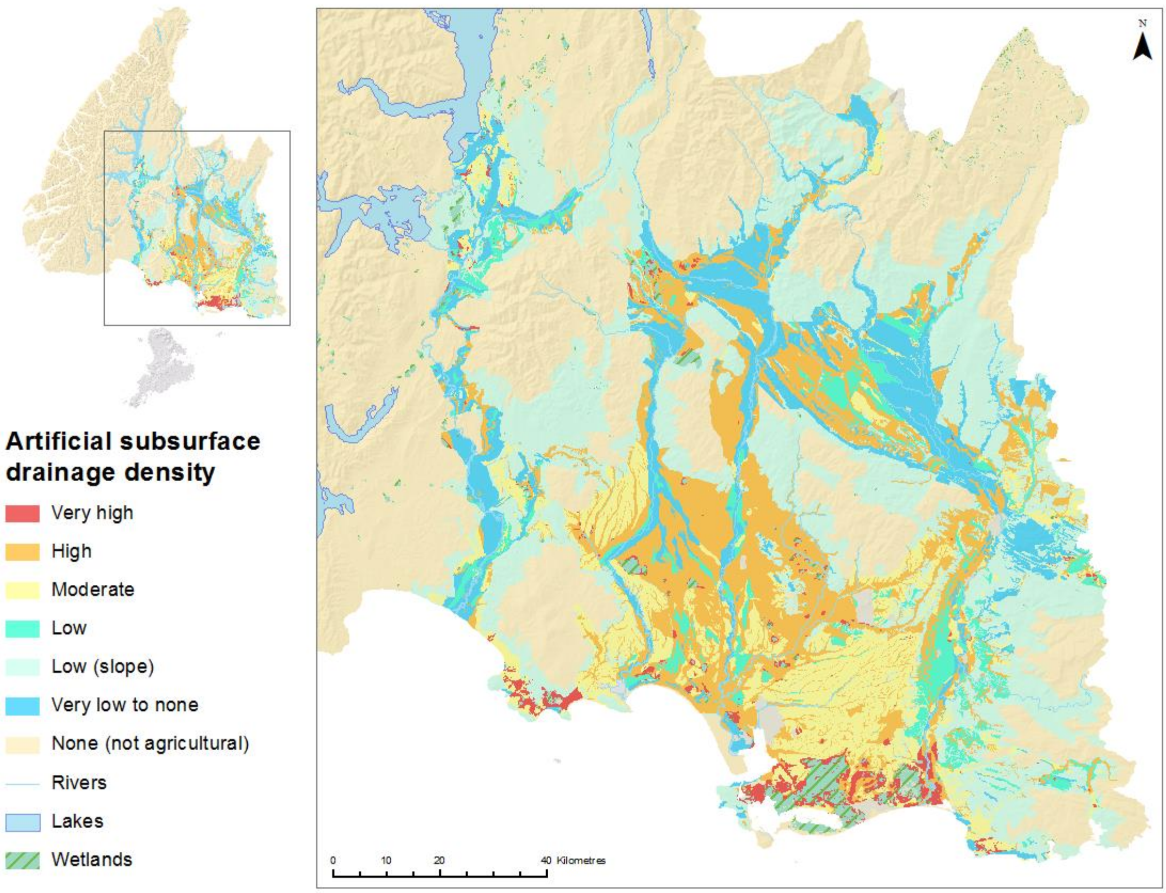

Figure A24: Densities of artificial subsurface drainage for agricultural land in Southland
Source: Pearson, 2015

Soil parent material also plays a role in determining pathways for nutrient losses from agricultural soils. Most soils in Southland are felsic, derived from greywacke, schist or silica-rich igneous (e.g. granite) parent materials and are slow to weather. In isolated areas, notably in the central southern plains, soils are mafic and ultra-mafic, derived from parent materials from the Tākitimu Mountains. These mafic rocks have a high concentration of iron, magnesium, and ferric oxide minerals making them particularly susceptible to weathering processes, resulting in clay minerals that tend to shrink or swell. These clay minerals have a marked seasonal effect on water quality in the Central Plains. In summer, when the soils dry and crack, water can bypass the soil matrix and flow through the cracks, increasing the risk of nitrogen loss and other substances into underlying aquifers. In winter, when the soils are saturated, water typically moves through the artificial drainage network into surface water networks with limited interaction with the soil.

The way that water drains through the landscape is controlled largely by the season or climate. In winter or extended periods of rainfall, the water table rises and water is able to move through the system faster resulting in less time for the soil to attenuate substances. In summer or drier conditions, the streams are less connected to the water bodies, as soil moisture is lower, artificial drains are not active and the depth to groundwater (or water table) is much lower. The risk of overland flow occurring is reduced as soils are not saturated. The result is strong seasonal differences in water quality. In Southland, the proportion of water drained by overland flow, lateral (horizontal or through artificial drainage systems) or bypass (vertical) flow is high.

2.3. Land Use Capability

Land Use Capability (LUC) is a classification system that was develop in the 1960s to assess and map soil and land resources across New Zealand at a scale of 1:50,000 (DSIR,1968). An LUC assessment rates the ability of land to support agricultural and forestry production using five factors: soil, rock, slope, erosion, and vegetation cover. It also considers climate, the effects of past land use, and the potential for erosion (Lynn, et al., 2009). There are eight LUC classes, ranging from Class 1 (good multi-use flat land) to Class 8 (steep land with severe physical limitations). Table A7 gives a description of these classes with estimates of the area of land in Southland and Figure A25 shows their distribution.

Table A7: Land Use Capability in Southland (adapted from Newsome, Wilde, & Willoughby, 2008)

LUC Class	Description	Land Area in Region (ha)	Share of Region
1	Good multi-use land, flat to very gently sloping, deep, easily worked soil, negligible risk of erosion.	1,097	0.0%
2	Flat to gently rolling land with slight physical limitations, may be used for cultivated cropping, horticulture, pastoral farming or forestry.	171,835	5.5%
3	Land with moderate physical limitations for cultivation; may be used for cultivated cropping, horticulture, pastoral farming or forestry.	387,589	12.4%
4	Land with severe physical limitation for cultivation; constraints on the choice of crops able to be grown; may require intensive soil and water conservation treatment and careful management practices.	302,244	9.7%
5	Too many limitations to be cultivated for cropping. Negligible to slight erosion risk under pastoral or forestry use. Typically stony, wet or sloping land with high quality, stable soils. Where slopes prevent cultivation some horticulture may be suitable.	35,852	1.1%
6	Moderate limitations for pastoral use. Suitable for forestry.	529,156	17.0%
7	Severe limitations for pastoral use. Suitable for forestry.	393,686	12.6%
8	Severe physical limitations; not suitable for any form of cropping, pastoral or production forestry use; only suitable for watershed protection.	1,195,908	38.4%
Other	Includes lakes, quarries and towns	100,602	3.2%
Total		**3,117,969**	**100.0%**

Of the eight land use capability classes, Classes 1 to 4 are usually suitable for cultivation, Classes 5 to 7 tend to be better suited to pastoral farming and forestry, while Class 8 is typically not suitable for any agricultural or forestry use and is usually left in indigenous forest or tussock grasslands for catchment protection. LUC is a productivity assessment; in general, it does not consider land use suitability, in terms of the receiving water bodies and soils[23]. The LUC classification system was used as one of the selection criteria for the sheep and beef case study farms (**Part C**).

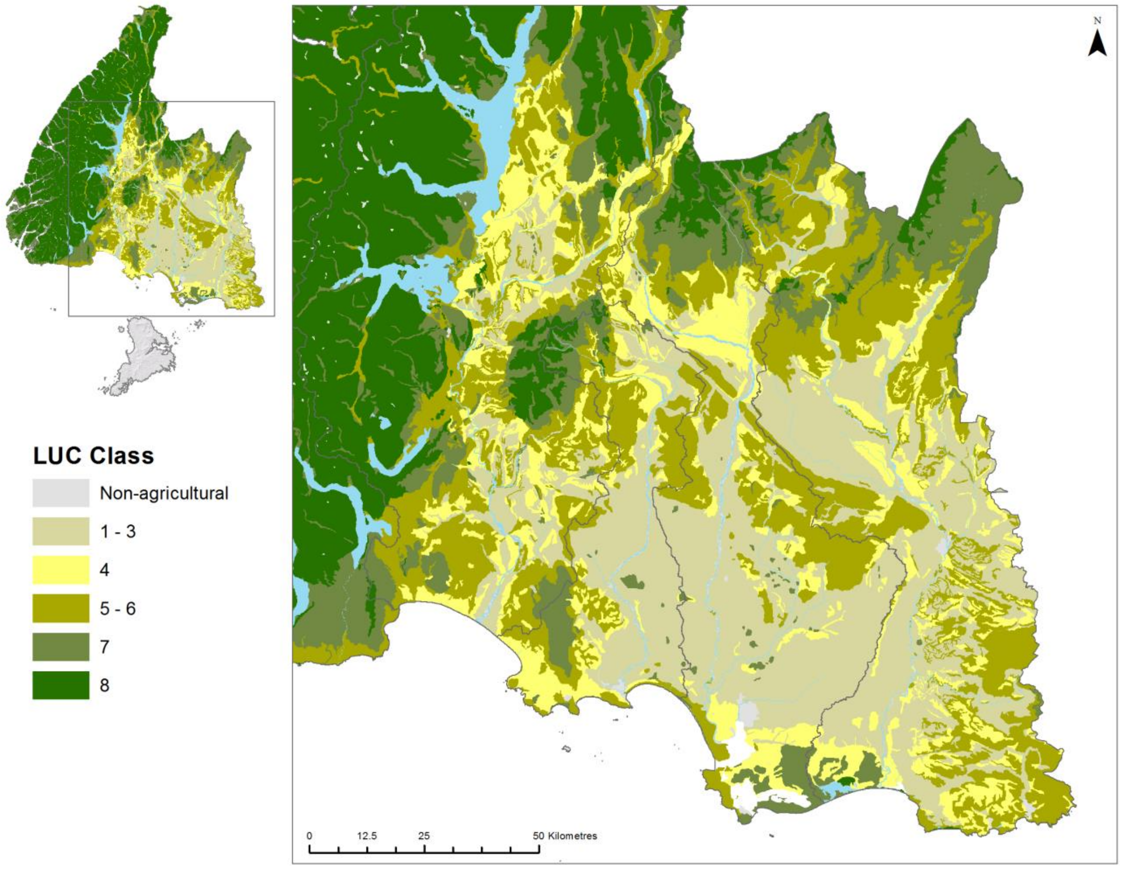

Figure A25: Land use capability classes in Southland

[23] Land use suitability is being investigated in the Our Land and Water National Science Challenge: Suitability Programme. A powerpoint presentation on this programme is available at http://www.ourlandandwater.nz/assets/Uploads/suitability.pdf

2.4. Physiographic Zones

Section 2 described how environmental conditions, and in particular precipitation and soils, are important factors (along with farm management) in the amount of nutrients lost from production systems. These factors were also used, along with geology, hydrology, and hydrogeology information, to identify patterns in Southland's hydrochemistry and water quality (Rissmann, et al., 2016). From these patterns, 29 'assemblages' (or groupings) with similar characteristics were developed that formed the basis of the nine 'physiographic zones' used in the proposed Southland Water and Land Plan (2016). The distribution of the nine physiographic zones is shown in Figure A26.

Three of the nine physiographic zones are in areas receiving rainfall or large volumes of runoff from headwater catchments (alpine sourced), each with different hydrochemical and water quality characteristics:

Alpine – high elevation areas receiving large volumes of dilute precipitation (including seasonal snowpack accumulation) falling on steep topography;

Bedrock/Hill Country – rolling to steep sub-alpine areas with carbon-rich soils receiving elevated rainfall and, in places, runoff from alpine areas; and

Riverine – recent alluvium along the margins of the major rivers where recharge from alpine and bedrock-derived catchments provides considerable dilution of local land surface recharge.

The remaining six physiographic zones are in flat to rolling lowland areas, where there is little to no dilution of drainage losses by water from Alpine or Bedrock areas. In these lowland areas, variation in the hydrology and chemistry of unsaturated (soil and undifferentiated rock and sediment overlying groundwater) and saturated zone (aquifer) is an important influence over water quality outcomes in terms of nutrients, sediments and microbes.

Oxidising – well-drained (oxidising) soils overlying (oxidising) alluvial deposits that are not flushed by dilute river waters;

Gleyed – imperfectly to poorly drained (reducing) soils overlying (oxidising) alluvial deposits that are not flushed by dilute river waters;

Lignite/Marine Terraces – well-drained to imperfectly drained (generally oxidising) soils overlying (reducing) sediments containing elevated organic carbon that are not flushed by dilute river waters;

Peat Wetlands – organic (reducing) soils overlying (reducing) aquifers containing elevated organic carbon with low phosphorus retention capacity that are not flushed by dilute river waters;

Central Plains – these are areas with similar characteristics to Gleyed, where the drainage mechanism (recharge) is seasonally distinct. During extend dry periods the clay rich soils shrink and crack so that aquifer recharge bypasses the soil zone so that denitrification and attenuation of nutrients and microbes is limited. As the clay rich soils rehydrate over the autumn and winter the drainage pathway shifts to the lateral soil zone through subsurface drainage. As with other lowland physiographic zones, the Central Plains are not flushed by dilute river waters; and

Old Mataura – areas with similar characteristics to Oxidising, where the highly weathered nature of soils (low organic carbon) and low to moderate permeability of underlying alluvial deposits, lack of flushing by dilute river waters limits the potential for attenuation and favours the build-up of groundwater nitrate to high concentrations.

The physiographic zones explain some of the variation in water quality across Southland, highlighting potential risks to water quality and, consequently, indicate where different mitigations are likely to be particularly useful. More detailed information regarding the spatial controls over water quality outcomes is available in the science that underpins these zones (Rissmann, et al., 2016).

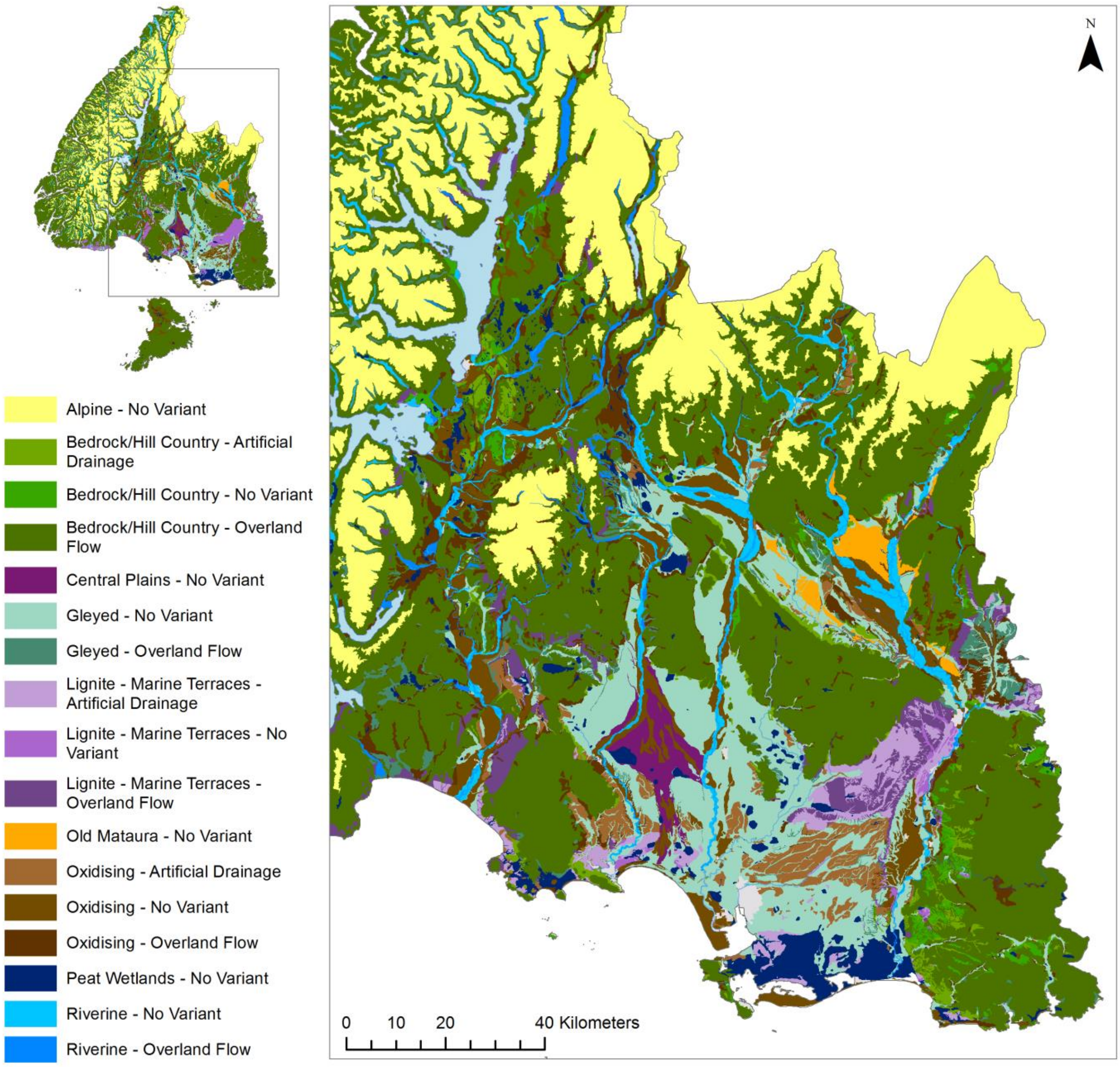

Figure A26: Southland physiographic units and variants

Part B: Agriculture and Forestry

There are marked variations between how agriculture and forestry occurs in Southland compared to other regions in New Zealand. In particular, the length of the growing season is considerably shorter than elsewhere, and there is more rainfall than in regions like Otago and Canterbury. In Southland, it is more challenging to carry stock over winter, and there are extensive soil drainage networks with less need for irrigation in many places. Regional differences such as these are variations on a larger scale to those that occur within Southland, notably around climate, soils and topography.

Part B is an overview of the agriculture and forestry sectors in Southland. It builds on the outline in **Part A** of Southland, particularly its climate and soils, and describes the development of industries within these sectors, describing their key features, their importance to the region, and the importance of Southland for each industry. **Part B** also gives a basic context that is helpful for understanding the methodology and results in **Part C**. In particular, it explains some of the connections and diversity within agriculture in the region, which have shaped the survey and modelling of the farm case studies. In doing so, it also underlines the need to tailor the general methodology specifically to each industry.

Part B is made up of seven main sections:

Section 1 is a general introduction to agriculture and forestry in Southland, and includes geographical extent, broad characteristics, and land cover.

Section 2 to **Section 6** look specifically at the agriculture sector and describes each of its main industries: sheep and beef farming, deer farming, dairy farming, arable farming, and horticulture (vegetables and tulip bulbs). These sections are largely written by representatives from each industry group.

Section 7 describes forestry in Southland, touching on indigenous forestry and farm forestry before concentrating on commercial plantation forestry.

1. Agriculture and Forestry in Southland

This section describes the geographical extent of the main industries within agriculture and forestry in Southland and their enterprise mixes. It looks on-farm to discuss general characteristics and it uses land cover to explore the ratios between effective and ineffective areas[24]. Highlighted are the connections between industries within the two sectors and also the diversity within agriculture.

[24] Effective area is an agricultural term used to describe the area of a farm actively used for food and fibre production (e.g. pasture and cropping), with the remainder being ineffective area (e.g. farmhouse and garden, shelter belts and woodlots, and wetlands).

1.1. Geographical Extent

Since development began in Southland at least 150 years ago, land uses has been continually changing over time with the evolution of different industries. Following New Zealand's deregulation of its markets in the 1980s, this rate of change has been rapid[25]. In recent years the main trend has been a shift from drystock farming (sheep, beef and deer) in two main directions:

1. There was a transfer in land use from high country pastoral leases to public conservation, with the creation of protected areas within the Department of Conservation estate. As a result of the tenure review process, the Tākitimu Mountains, Eyre Mountains and Snowdon Forest were added to the Department's Conservation's estate in 1997 and 1998, and reclassification of Crown land led to Rakiura National Park (Stewart Island) opening in March 2002; and

2. There was a shift in land use from lowland drystock to dairy as the dairy industry expanded. Between 1990 and 2014 there was an estimated 30 percent decline in the total area of land in Southland for drystock – from roughly 1,100,000 hectares to 795,000 hectares – and an increase in the area for dairy from 16,000 hectares to 255,000 hectares.

Many lowland drystock farms in the region either diversified from sheep to other enterprises or shifted away from sheep altogether and into dairying. Beef farming remained more stable, through some substitution of beef for sheep and because beef cattle tend to be run on land not sought after for dairying in Southland. Agricultural land also switched from drystock and arable farming to activities connected with the dairy industry, such as the grazing of mixed age dairy cattle. Figure B1 shows changes in land use in Southland between 1996 and 2015 and the 59 percent of the region (1.89 million hectares) that is in indigenous vegetation (a combination of indigenous cover and conservation). The majority of the land in indigenous cover is LUC Class 8 (refer to Part A: Section 2.3) and at higher altitudes. Agriculture and forestry occurs on 38 percent of the land in the region that is mostly at lower altitudes.

The estimates in Figure B1 are based on information from The Southland Land Use Map[26] (April, 2015)[27] shown in Figure B2. This map is included to give an idea of the distribution of land uses across Southland but the size and technical detail included in this highly technical map makes it difficult to view the region as a whole at this scale and resolution.

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[25] Ledgard (2013) gives a detailed analysis of land use change in Southland since 1860.

[26] The estimates are determined using the Southland Land Use Map (April 2015) (Pearson & Couldrey, 2016). The Southland Land Use Map identifies farms by the presence or absence of stock types and most of the agricultural data used was sourced from Agribase™.

[27] Identification of these areas is explained in the development of the Southland Land Use, Technical Map (Pearson & Couldrey, 2016).

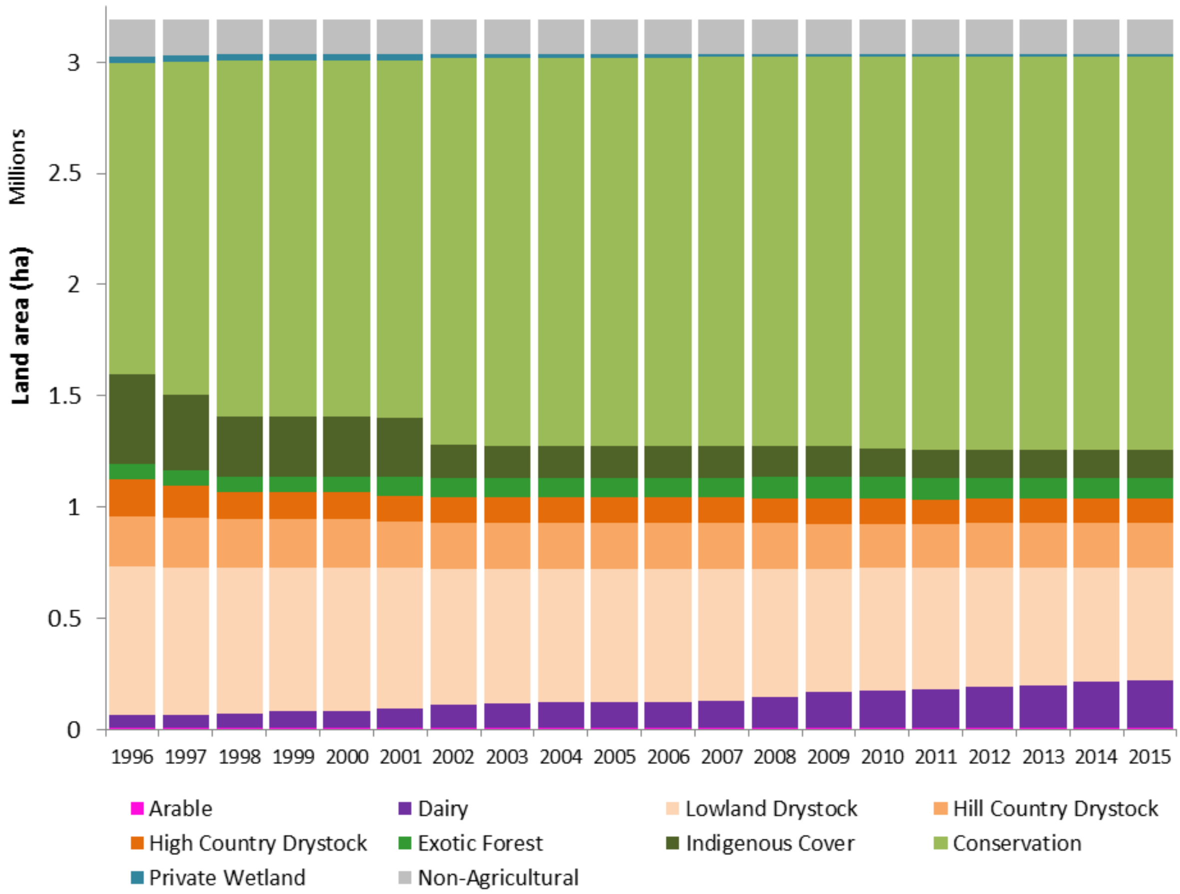

Figure B1: Land use change in Southland 1996-2015
Source: Pearson and Couldrey (2016)

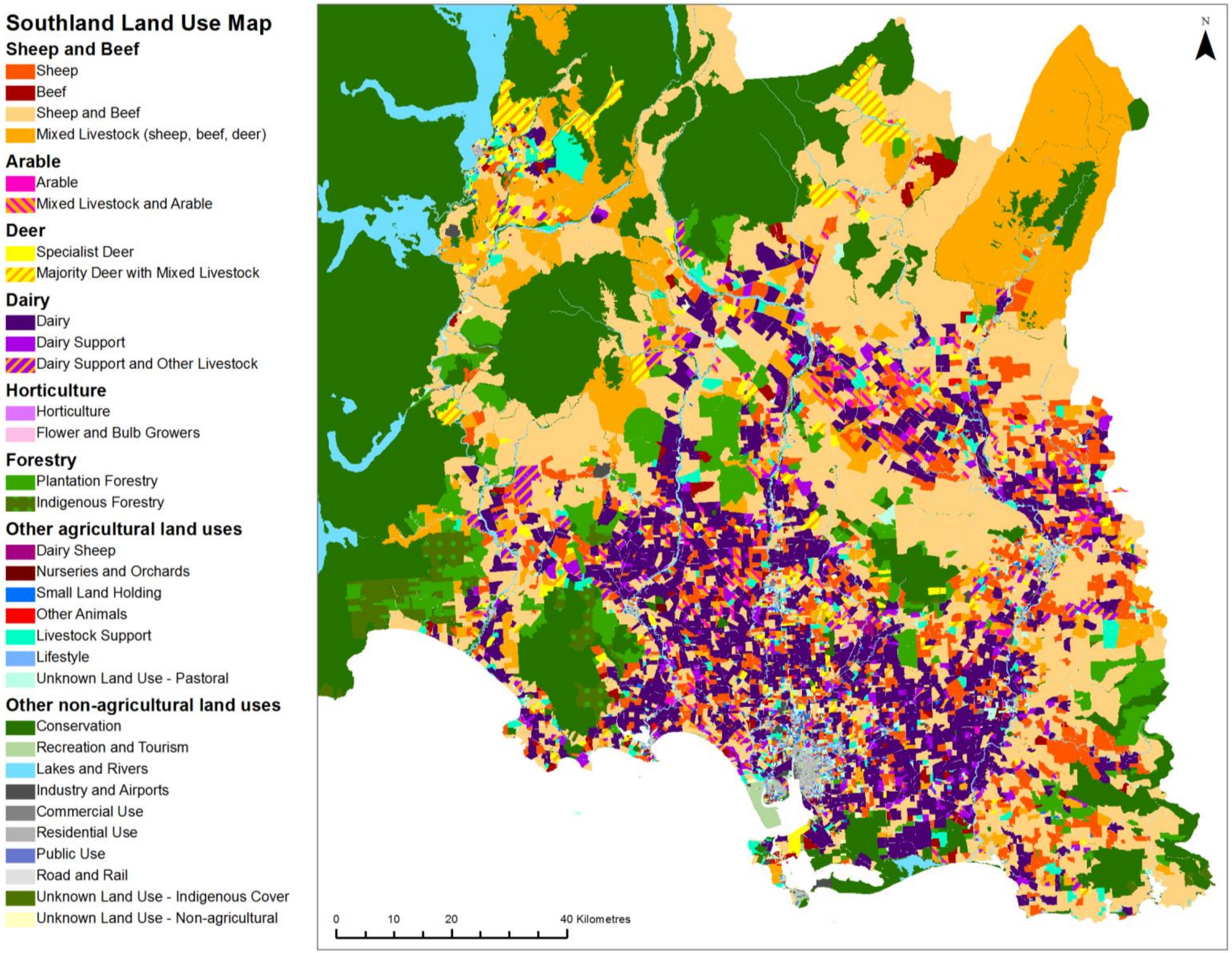

Figure B2: Southland Land Use Map 2015
Source: Southland Land Use Map, April 2015 (Pearson & Couldrey, 2016)

Although the agricultural and forestry sectors, and the industries within each sector, appear as distinct from each other, they are in fact strongly connected (both positively and negatively). Many farm businesses are either involved in, or supporting, a range of enterprises and land uses over one or more properties. The developed land in Southland is essentially one large farm with fences. An industry's connections highlight how it operates within a region and nutrient losses related to an industry can occur on other land uses. These connections are important considerations in understanding how the impacts of policy are likely to flow between industries and on through the wider regional economy.

The industry classes for agriculture and forestry used on the Southland Land Use Map are:

Sheep and Beef: Sheep and Beef; Sheep; Beef; and Mixed Sheep, Beef and Deer;

Arable: Arable and Mixed Livestock; and Specialist Arable (but not crops grown for winter grazing);

Deer: Mixed Sheep, Beef, and Deer (Majority Deer with farms > 45% deer); and Specialist Deer;

Dairy[28]: Dairy; Dairy Support[29]; Dairy Support and Other Livestock;

Plantation Forestry: Plantation Forestry (Exotics); and Indigenous Forestry.

Other: Livestock Support[30]; Small landholdings (5-40 hectares); Lifestyle (<5ha); Other Animals; Sheep Dairy; Horticulture; and Unknown Pasture[31]

Many drystock farms rely on integrated grazing management where a mix of different stock classes (each with differences in the timings of feed demands and production requirements across the year) is used to maintain pasture quality. Drystock farms are also involved in dairy support, or grow arable crops, and some of these farms lease land to horticultural growers. Similarly, mixed age dairy cattle are often grazed in winter off the milking platform on either specialist support farms, sheep and beef farms or arable farms, and dairy heifers are raised and/or grazed on some of these farms. For drystock, the connections with other industries usually occur on the farm, whereas for dairy these connections more often than not are beyond the farm gate.

In addition to cattle dairy, there is one firm in Southland that processes sheep dairy products. Blue River Dairy was established in 2003, and produces specialty sheep's milk cheeses along with sheep's milk infant formula, milk powder and ice cream. There are three farms located in Southland (947 ha) with East Friesian sheep that are bred with other breeds to be hardier in the Southland climate.

Arable farming has strong connections with the other agricultural industries, in part because of the rotational nature of arable crops around grazing livestock. Another reason is the wide use of arable

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[28] Dairy properties are identified by the dairy milking platform only, through the Environment Southland Dairy effluent discharge area. Dairy Support and Dairy Support and Other Livestock categories show the number of dairy properties with additional land off the milking platform. The difference between dairy and the two dairy support categories is the number of dairy properties that either winter cows on-farm or use a grazier over winter.

[29] Dairy Support is classified in the Southland Land Use Map as the 'dairy' identified by Agribase that is not on the milking platform (identified by Environment Southland Resource Consent). As Agribase has identified the property for dairy use, it is included in the Dairy Industry.

[30] Livestock Support is most likely to be additional dairy support land but the type of livestock grazed on a property is unknown so it is not allocated to a specific industry.

[31] Unknown Pasture is not included in Figure B3 because of the relative uncertainty with the property count for this category. Unknown Pasture land is most likely to be used for sheep and beef farming but it is classified as Unknown Pasture because there is no specific data source in the Southland Land Use Map that identifies these properties.

crops for stock feed – both on-farm and off-farm. The importance of arable farming in Southland is not fully reflected by either land area or number of arable farms because many pastoral properties grow arable crops. Wintering livestock by break-feeding on forage crops is common practice in Southland as pasture growth over winter is minimal. Crops commonly used as winter livestock forage crops are kale, swedes and turnips along with other brassica varieties, fodder beet, and oats – research has highlighted the in-situ grazing of stock on these crops can make a disproportionately large contribution to nutrient losses from a farm (Pearson, Couldrey, & Rodway, 2016).

Image B1: Stokes of oats for chaff, Lochiel
Source: Simon Moran

Land area and number of properties each paint a different picture of an industry at a point in time. For example, there are far more deer properties around Invercargill compared to the Te Anau Basin yet deer farming in Te Anau covers a much greater extent. Both number of properties and land area are important for understanding the possible socio-economic impacts of policy over the short to medium-term, alongside other measures, such as employment. Figure B3 and Figure B4 show the geographical extent of these industries by number of properties[32] and land area. These graphs highlight some of these connections and the enterprise mixes for each industry. For instance, roughly half of sheep and beef properties are mixed operations, with some combination of sheep/beef and deer enterprises. Where deer is a minor stock type in mixed livestock systems the property is included as being sheep and beef. A large proportion of arable properties are a mix of arable and livestock enterprises.

[32] Properties are used rather than farms because information on the number of properties within a farm business is not easily available.

Many deer properties also run other livestock but quite a few are specialist deer. Where deer is the major stock type in a mixed livestock system the property is included as deer. Roughly two-thirds of dairy properties are milking platform only and one-third also own a dairy support run-off. Horticulture (included in the "Other" category) occupies a small area of land because it tends to occur on land leased from sheep and beef farms. Almost all of the commercial forestry area in Southland is plantation forestry but there are small areas of native (or indigenous) forestry. Other aspects of farming enterprises not shown on this map (e.g. areas of farm forestry, intensively grazed winter crop, and ineffective areas) are discussed further on in this report.

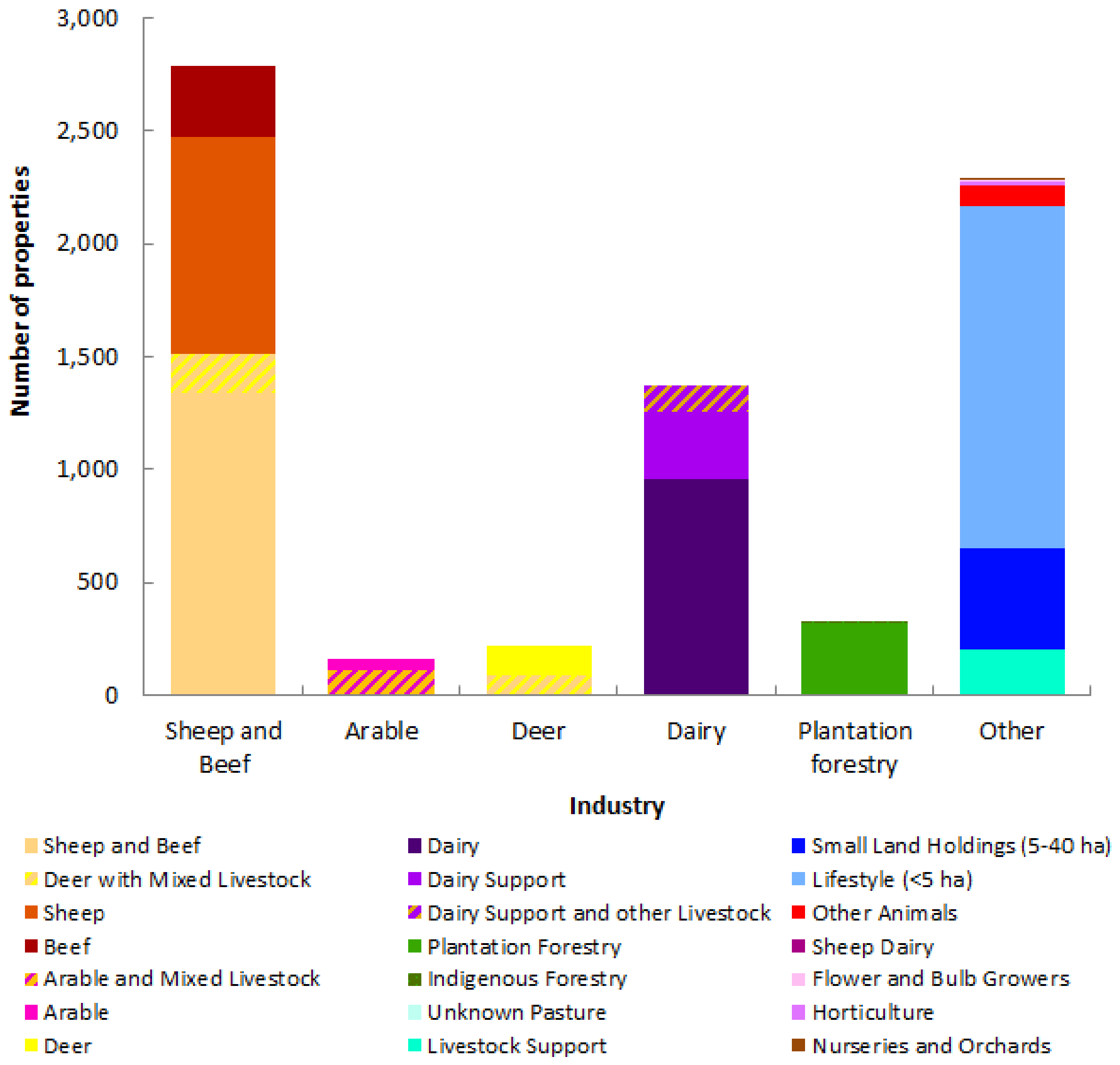

Figure B3: Distribution of properties by land use and industry in Southland 2015
Source: Southland Land Use Map, April 2015

The industry connections can mean the defining lines between industries are not as clear cut as may appear at first glance. Whether a property is identified as sheep and beef, or deer, or arable is often quite arbitrary and can depend, to a large extent, on how it is measured – for instance, the majority of farm area in an activity versus a farm's principal source of income. How a farm is measured depends on a farm's definition – whether it is as a property, or a business, or by ownership. As well, farm definition can also be influenced by farmer perception (i.e. what they identify as).

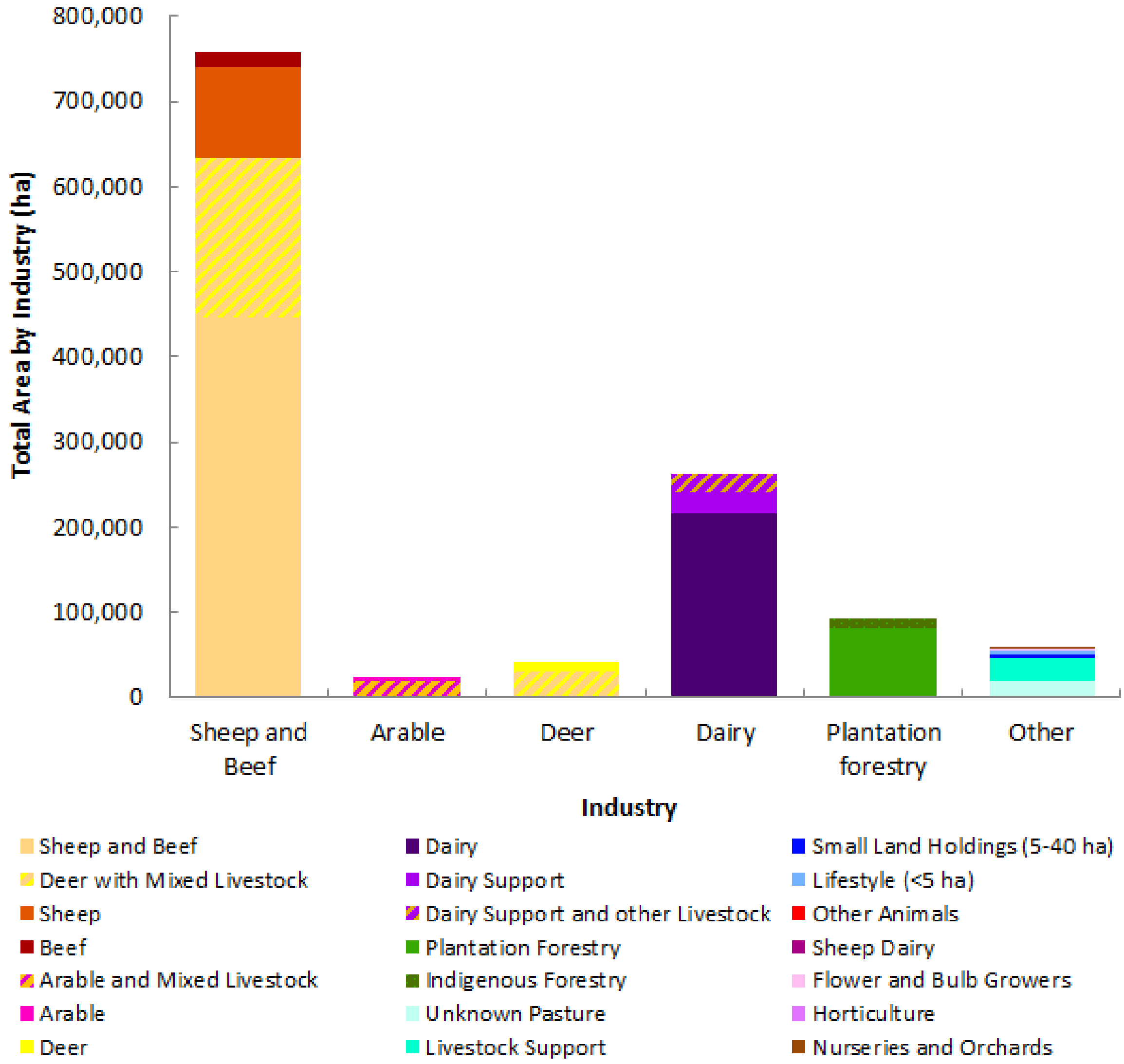

Figure B4: Distribution of land area by land use and industry in Southland 2015
Source: Southland Land Use Map, April 2015

Although there is common ground across agriculture and forestry, the graphs also highlight the diversity, particularly within agriculture. There are considerable differences across the region in terms of characteristics like farm size, slope, built infrastructure, and management. While this diversity occurs across all agricultural industries, it is particularly the case for drystock and arable. Diversity is usually driven by the variation in the nature of the land and the climate, but is also influenced by more human aspects, such as farmers' skills and experience, and their values and beliefs. The next section looks at some of these characteristics in more depth.

1.2. Broad Characteristics of Farming in Southland

Farming in Southland covers a range of topographies and climates, from largely flat coastal plains to extremely steep inland high country, and where a farm is located determines its environmental conditions. These conditions, in turn, influence the land use options available and, to a limited extent, farm management (use of inputs like fertiliser or imported feed, effective area and possible enterprise mix). Across Southland, there is a wide range of farm sizes from lifestyle blocks to high country stations.

In general, dairy, arable, horticulture, intensive drystock farming and some plantation forestry are located on flat to rolling land. Extensive drystock farming and plantation forestry are more often found in the hill and steep areas. Farms on flat land are often relatively small and operate more intensive farming systems. The land is usually highly productive (and consequently has a higher value), has a high proportion of effective hectares, and carries higher stock numbers. This land is versatile and can be used for a range of farm production systems. Farms that include steeper country tend to be larger and operate more extensive farming systems. The land tends to be less productive, has lower proportion of effective hectares and consequently supports a lower stocking rate (stock units per effective hectare or SU/eff.ha)[33]. Since the 1990s, drystock farming and plantation forestry has shifted towards the steeper land, where there is less competition with other land uses.

Beyond these basic generalisations, every farm in Southland is unique; and any farm is, at best, only indicative of how farming occurs within a specific industry or locality. In reality, there is no such thing as an average farm because there are so many different ways that a farm can be measured and operated. The following sections of this report will highlight this point.

"We have to look at things farm by farm to get a true picture of what is going on"

John Somerville – Pinebush deer farmer (pers. comm., 2016).

Dairy is the one industry that is aimed at producing a single product and its production systems largely vary by the timing, purpose and amount of imported feed used, in addition to that grown on-farm. All other systems have multiple products with many different approaches to optimising production. In arable and horticulture several different crops may be grown in rotation on the same block of land in any given year, with each crop being market driven. These systems are highly flexible and there can be rapid changes in crop choice and planned rotations.

Drystock farming is predominantly aimed at the production of meat, wool and deer velvet. It is a continuous process that follows an annual cycle, fitting both its pasture production and markets.

[33] One stock unit is the equivalent of one ewe with a lamb at foot. Hoggets, wethers and rams are less than one stock unit. Mixed age beef cows are the equivalent of 5.5 stock units and grazing dairy cattle are 4.5 stock units. By comparison, Jersey cows are 6.5 stock units and Friesian cows are 8.5 stock units. More information on stock units is available at http://portal.beeflambnz.com/tools/benchmarking-tool/definitions

While there are roughly as many sheep farms as there are sheep and beef farms in Southland, beef farms are less common. Around three-quarters of deer farms also run sheep, beef or dairy grazing. Drystock farming occurs on a wide range of slope classes and soil types, and a main feature is the variability in many of the underlying components of production, resulting from on-going adaptation to environmental conditions. It has limited use of inputs that increase the land's capacity to carry stock (e.g. fertiliser or imported feed), which mean fewer options available for managing nutrient losses. This situation is not peculiar to Southland and has been identified elsewhere, e.g. in Waikato by drystock farmers:

> *"We see dairying as relatively simple technically, [and] sheep and beef [as] much more complex. Dairying [has] one set of animals, all mature stock running on high class land, [while] sheep and beef farmers may have sheep, beef, deer, goats, [and] maybe dairy grazing, all on one production unit with varying classes of land… technically different sorts of farms."* (Cameron, Barrett, Cochrane, & McNeill, 2010).

The differences in production systems between dairy, drystock and cropping industries were a major consideration in the design of this research.

1.3. Land Cover

Analysis of land cover (e.g. pasture, crops[34], native forest, and wetlands) highlights the importance of considering farms as a whole farm system, rather than focusing on their main land use. In general, drystock has a higher proportion of extensive pasture and forest (exotic and native), while dairy has a smaller proportion of extensive pasture and forest. On arable farms there is usually more pasture than crops at any one time because arable farms mix crop and livestock, with the cropping enterprise rotating around a farm. Figure B5 and Figure B6 show the area and proportions of different types of land cover within each agricultural industry in Southland.

Land cover indicates how an industry's total land area is split between 'effective' area and 'ineffective' area. Effective area is an agricultural term used to describe the area of a farm actively used to produce food and fibre (e.g. pasture and cropping), with the remainder viewed as ineffective area (e.g. farmhouse and garden, shelter belts and woodlots, and wetlands). Ineffective area is a misleading term because it is not generally unproductive. These areas play an essential 'supporting role' in a farm system and the wider catchment. For example, tussock grasslands and shelter belts provide shelter for young stock (particular necessary in Southland as up to 40 percent of the region's strong winds occur in spring), and riparian margins encourage biodiversity, including bees that are vital for pollination of crops. The nutrient losses from the ineffective area of a farm are low, and essentially 'dilute' the usually higher losses from a farm's effective area. Some ineffective areas, such as wetlands, can also catch and take up a farm's nutrient losses.

Effective area is estimated using the Southland Land Use Map, by including the extent of grassland or cropland for pastoral/arable land uses, and planted exotic forest area for plantation forestry.

[34] The winter forage crop area shown in Figure B5 was estimated by the Winter Grazing Assessment conducted by Environment Southland (Pearson, Couldrey, & Rodway, 2016). It indicates the area where crop was grown in Southland over winter 2014 from imagery produced by Landcare Research (North & Belliss, 2014).

Ineffective area includes: lakes and rivers, wetlands, roads, houses and planted/indigenous forest for pastoral/arable land uses; or grazed or cropped pasture for plantation and indigenous forestry.

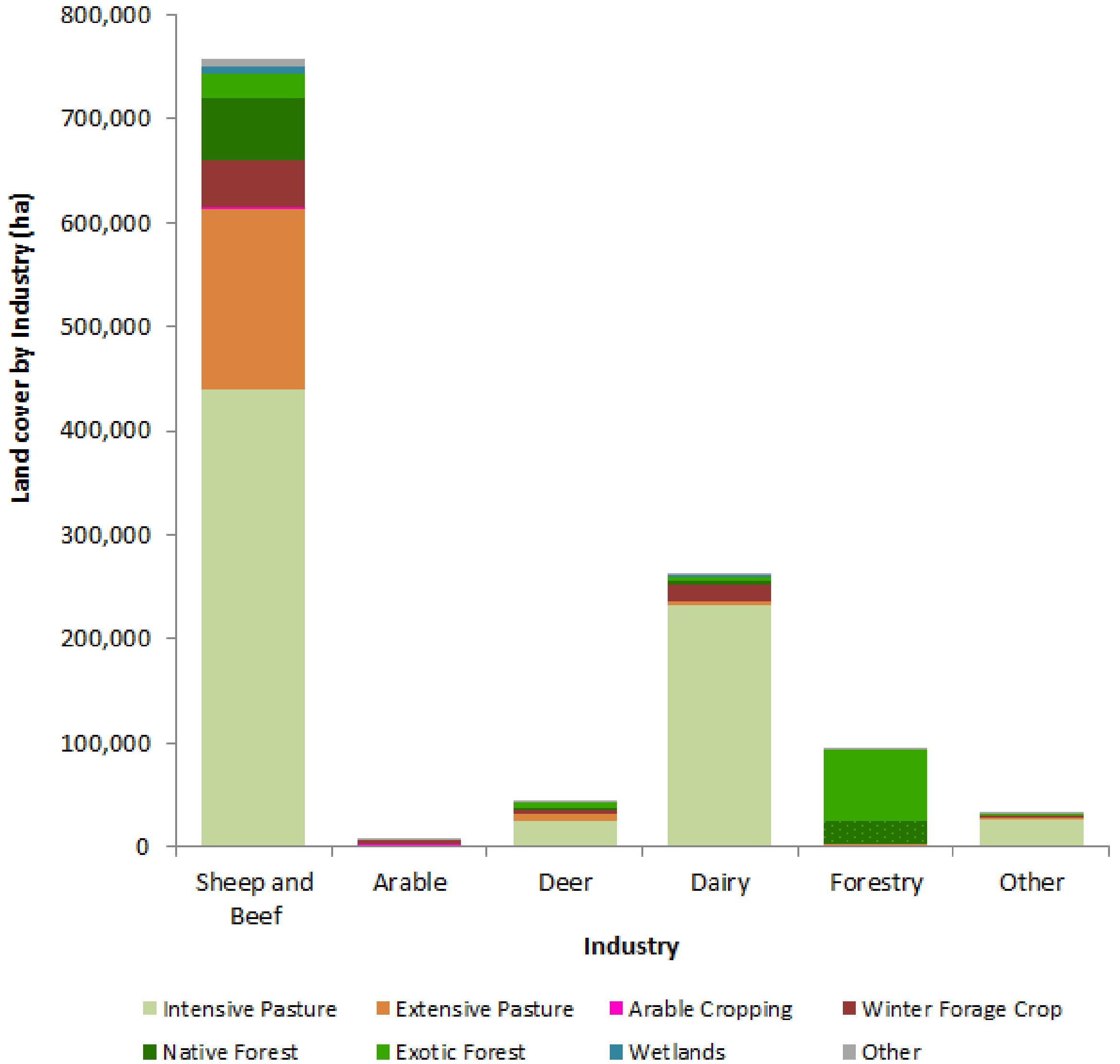

Figure B5: Land cover area by industry in Southland 2015
Source: Southland Land Use Map, April 2015; LCDB4.1

Areas described as 'effective' in OVERSEER are the areas that can be modelled, regardless of whether they are effective in the production system (as defined above). Data is entered into OVERSEER by farm blocks with similar management and environmental characteristics (e.g. topography and soil types): pastoral blocks, crop blocks, tree blocks, and house blocks etc. For example, a block identified as 'Trees and Scrub' has a default low rate (≤ 3 kg N/ha/year and 0.1 kg P/ha/year). Nutrient losses from house blocks are proportional to the number of houses on the farm, the number of people living in the houses, the wastewater treatment system, the rainfall, and the cultivated area of vegetable and flower gardens. The way house blocks are modelled in OVERSEER depends on the land use (e.g. dairy, sheep and beef).

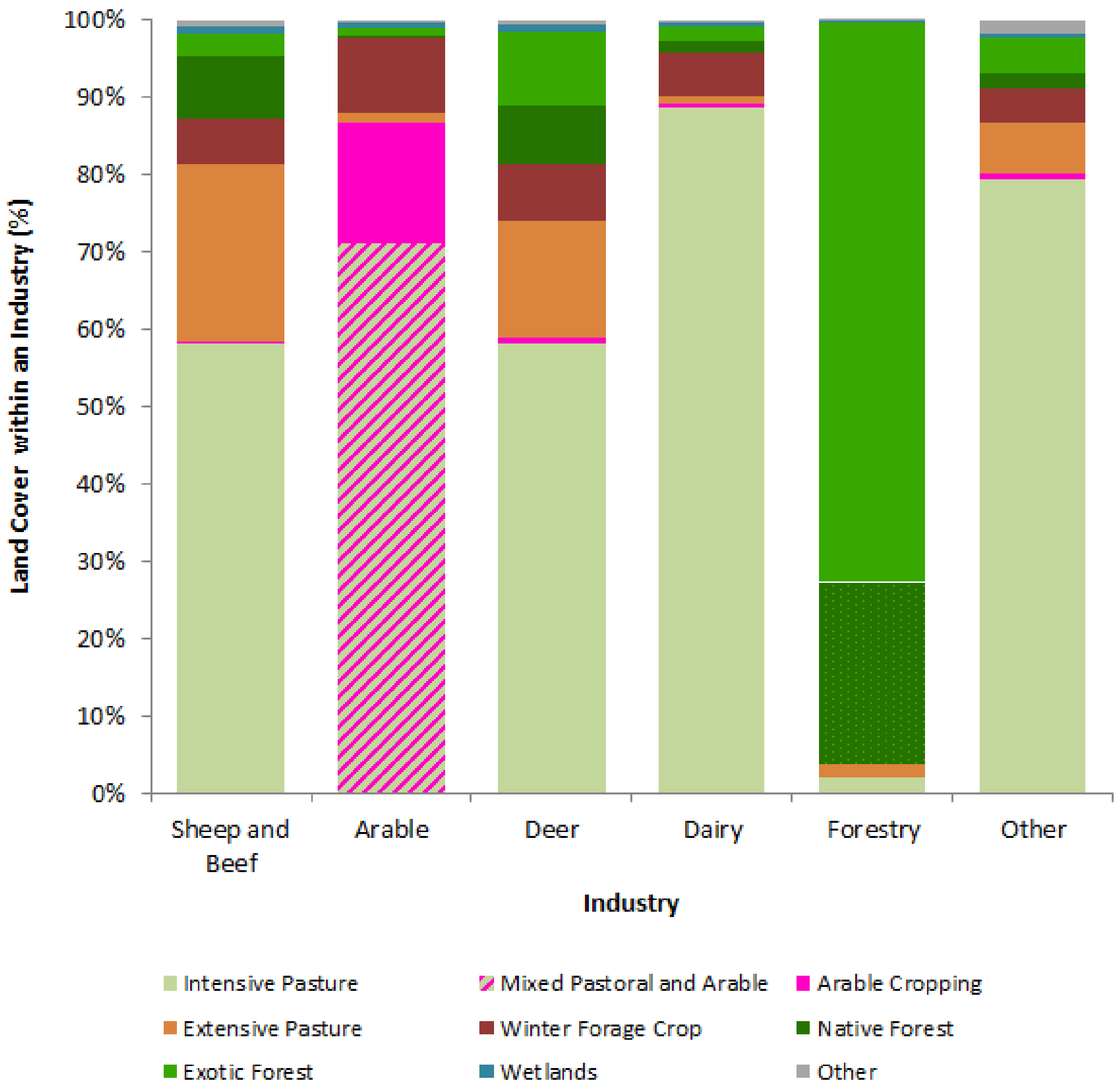

Figure B6: Proportion of land cover area by industry in Southland 2015
Source: Southland Land Use Map, April 2015; LCDB4.1

There are also 'non-productive' areas (lanes/races and yards) that are not modelled and given no nutrient losses. If the 'non-productive area' of the farm is not recorded in a farm's OVERSEER budget, a percentage of the 'pastoral' blocks is calculated to determine the ineffective area of the farm. Trees, houses and ineffective areas are typically considered 'ineffective' for the production system; however as they all contribute nutrients lost from the farm are calculated in the wider nutrient budget within OVERSEER. Care needs to be taken when comparing effective area (used for production) and the modelled effective area in OVERSEER. The following sections in **Part B** describe each of the main agricultural and forestry industries to give some context for the research in **Part C**.

2. Sheep and Beef Cattle Farming

Authors: Andrew Burtt (Chief Economist), **Beef + Lamb New Zealand**; and **Environment Southland** staff.

Sheep and beef cattle farms are the main type of drystock farms in Southland, the extent of which is shown in Figure B7. Most farms are either sheep-only farms, or mixed livestock (sheep, beef cattle and some deer). These farms are also the most predominant land use in Southland, covering roughly 56 percent of developed land. Sheep and beef farming is a diverse industry and no two farms are the same. Over the last 30 years, improvements in productivity have balanced decreases in total stock numbers and land area, and as a result production (or total yield) has stayed relatively constant.

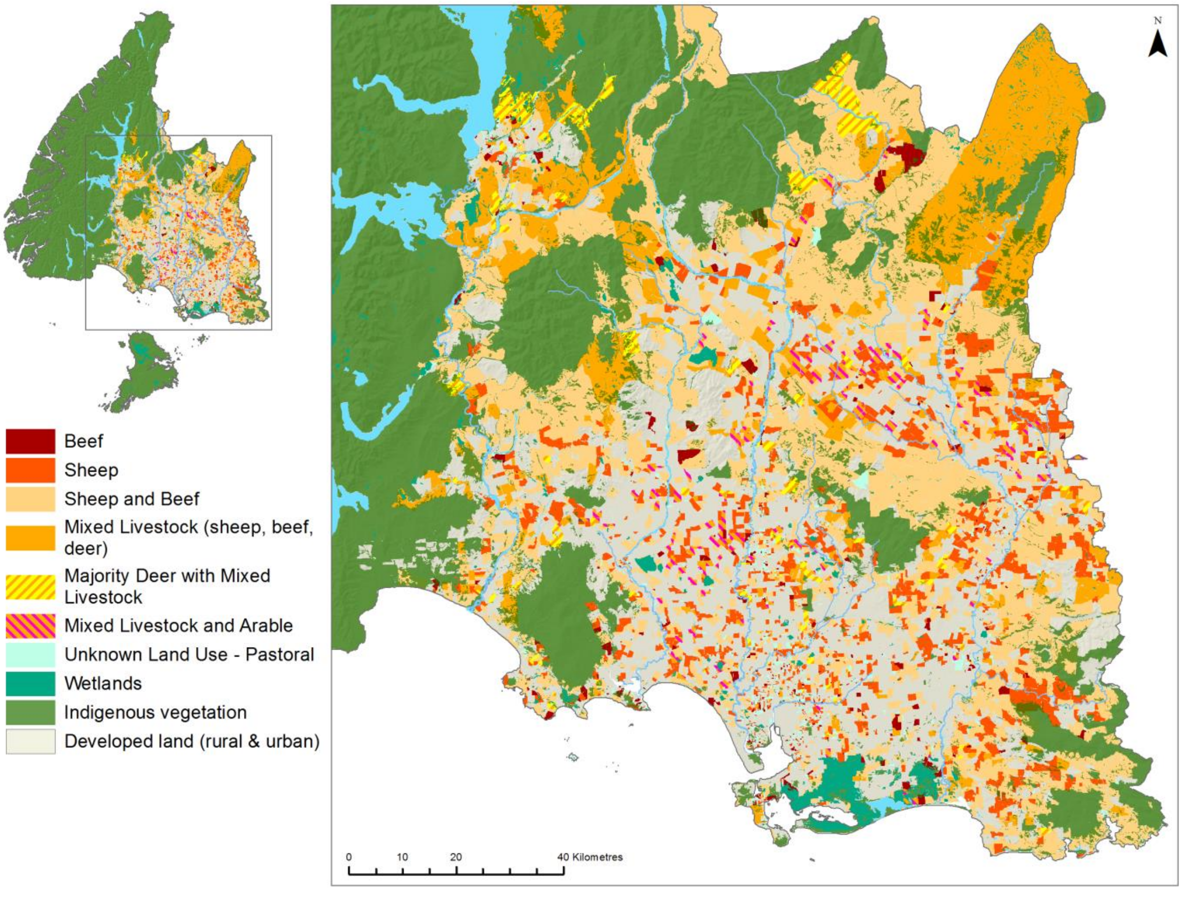

Figure B7: Sheep and beef cattle farming in Southland 2015
Source: Pearson and Couldrey (2016)

Sheep and beef cattle are typically run together on drystock farms in New Zealand. Generally, the two types of stock complement each other for a number of reasons. For instance, sheep and beef cattle have different feed requirements so pasture growth and usage can be balanced within a farm across the year. Beef cattle are used to manage surplus feed in summer and autumn resulting from rapid pasture growth, particularly on hill country, where there is a limit to the harvesting of grass for hay, baleage or silage. Sheep and cattle are generally not affected by the same types of parasites, so they both can be used to manage pasture while minimising exposure to parasites. Sheep and cattle have different revenue streams so running both stock is a way of diversifying the farm business.

Almost all commercial sheep and beef farms have some other form of revenue, e.g. from deer, arable crops, grazing other people's livestock, such as dairy heifers, and farm forestry. The proportion of income generated on sheep and beef farms in Southland from other enterprises varies considerably – from near zero to almost 50 percent. These multiple revenue streams, and the way that different livestock classes interact with each other, mean sheep and beef farms are complex businesses to operate, analyse and understand. This complexity has made the research detailed in **Part C** of this report particularly challenging.

2.1. History of Sheep and Beef Farming in Southland

Sheep and beef farming has dominated Southland's agricultural sector over the past 150 years. The first pastoral farmers in the area, which first became part of the province of Otago and later Southland, were former whalers who shifted into farming after 1850 when the whaling stations closed (Grant, Updated 2015a). Pastoral farming became more widespread as land in Canterbury and further north became scarce and farmers moved south (McLauchlan, 2006).

Over time, sheep and beef stock numbers and land area have fluctuated but accurate long-term land use information is absent, including those areas occupied by sheep and beef farms. Consequently, stock numbers are typically relied upon to indicate the expansion and intensification of sheep and beef farming (Ledgard G. , 2013). An overview of historical trends in stock numbers for sheep and beef (and other stock types) is available in (Ledgard G. , 2013) *Land use change in the Southland region: technical report*.

The development of frozen meat exports and spikes in wool prices drove strong growth in the number of sheep in Southland through the late 19th and early 20th centuries. By 1950 the region's sheep flock had reached three million animals. A wool boom and subsequent government policies encouraged expansion of the industry and led to sheep numbers peaking at over nine million by 1985. During this period, many dairy farms converted to more profitable meat and wool production (Cutt, 2006), though farm conversions had slowed by the mid-1980s with government deregulation of markets. Numbers of sheep then declined steadily through the 1990s and early 2000s. Sheep numbers stabilised in 2015 at around four million, and making up 15 percent of New Zealand's total sheep flock of just under 30 million (Statistics New Zealand, 2016a).

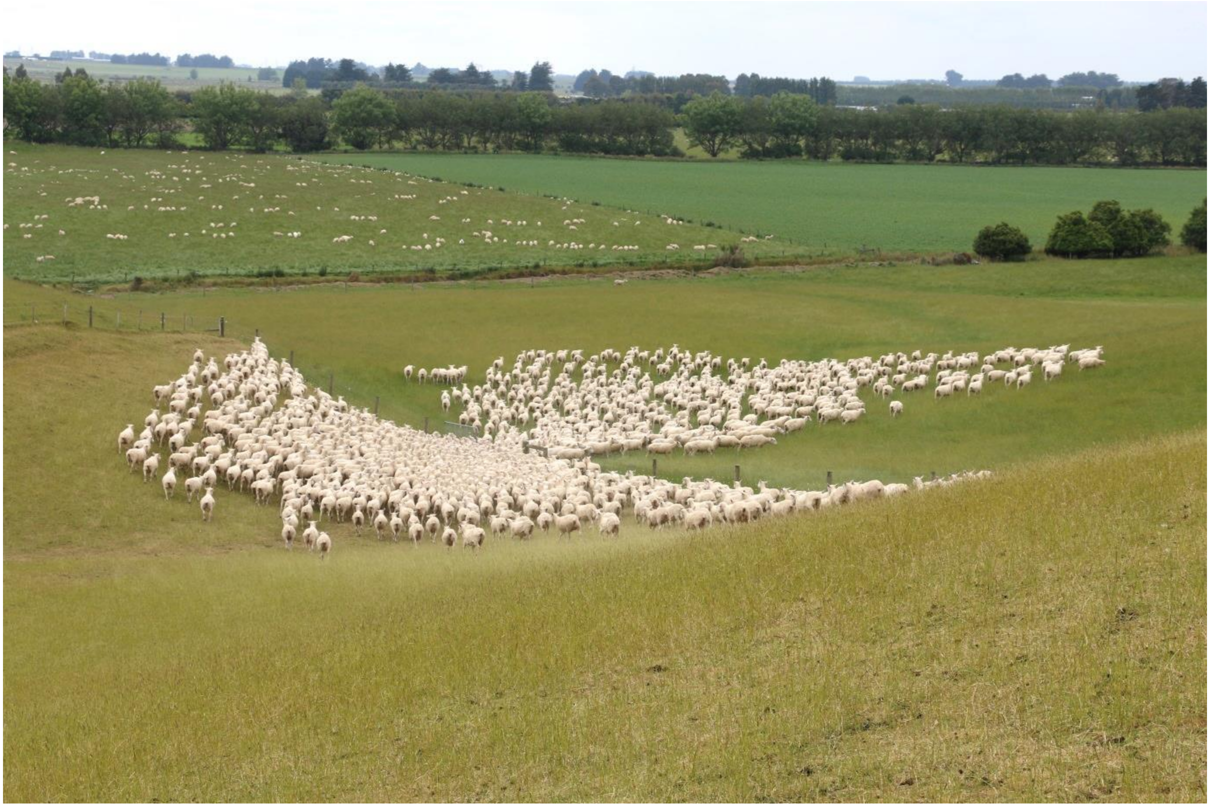

Image B2: Sheep in the Aparima FMU
Source: Simon Moran

The number of beef cattle increased steadily from 1860 to the mid-1970s to a peak of 301,000 head. Numbers then declined steadily following market deregulation in the 1980s, to a low of 170,000 in the early 1990s. From the late 1990s the number of beef cattle fluctuated between 172,000 and 215,000, and in 2014 there were 174,000, or roughly five percent of the total for New Zealand of 3.67 million beef cattle. These fluctuations in stock numbers were driven by changes in the relative profitability of the different enterprises within sheep and beef farms.

In the decade from 2004 to 2014, the number of sheep in Southland declined by 1.7 million (-28%), while the number of beef cattle declined by just under 50,000 (-20%). The decline in the region's absolute number of sheep was second only to Canterbury. Other regions (Otago, Waikato, Hawke's Bay, and Manawatu-Wanganui) also had declines in their flocks of more than half a million sheep during the same period. These regional changes in sheep and beef numbers are shown in Figure B8 and Figure B9.

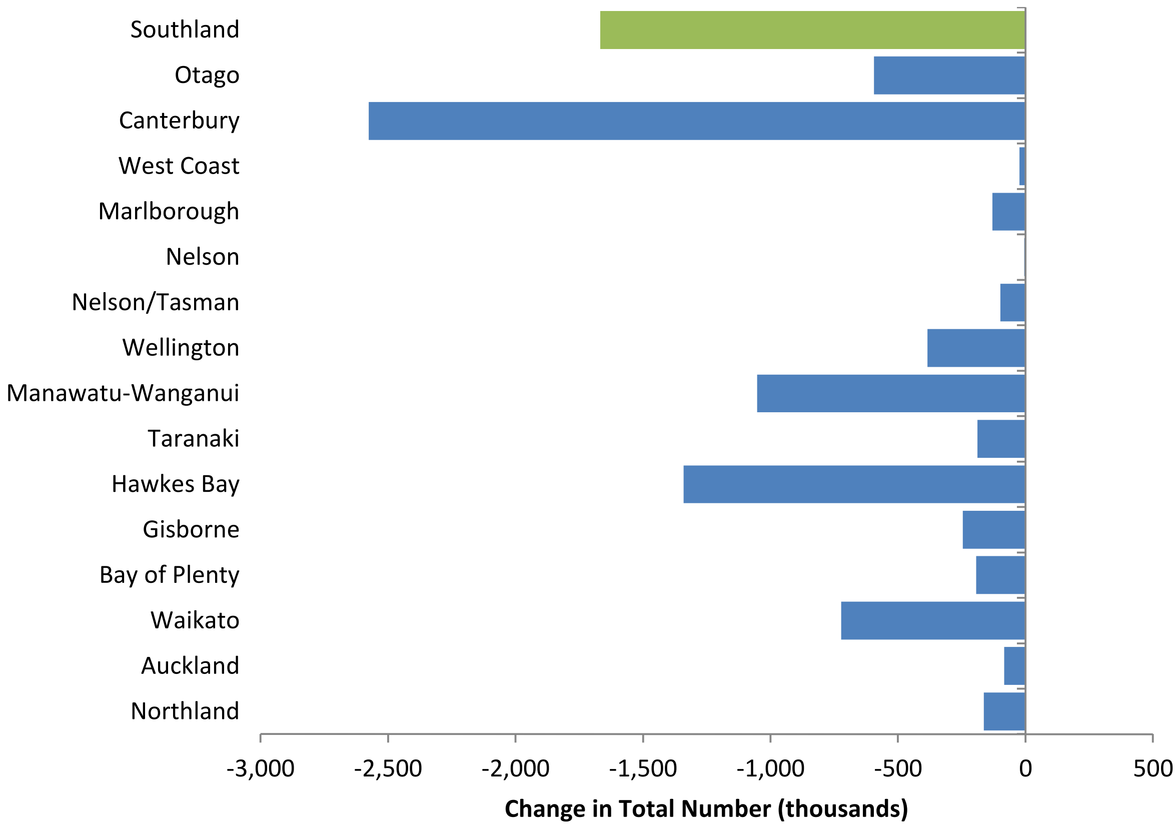

Figure B8: Change in sheep numbers by region 2004-2014
Source: Statistics New Zealand Agriculture Production Statistics

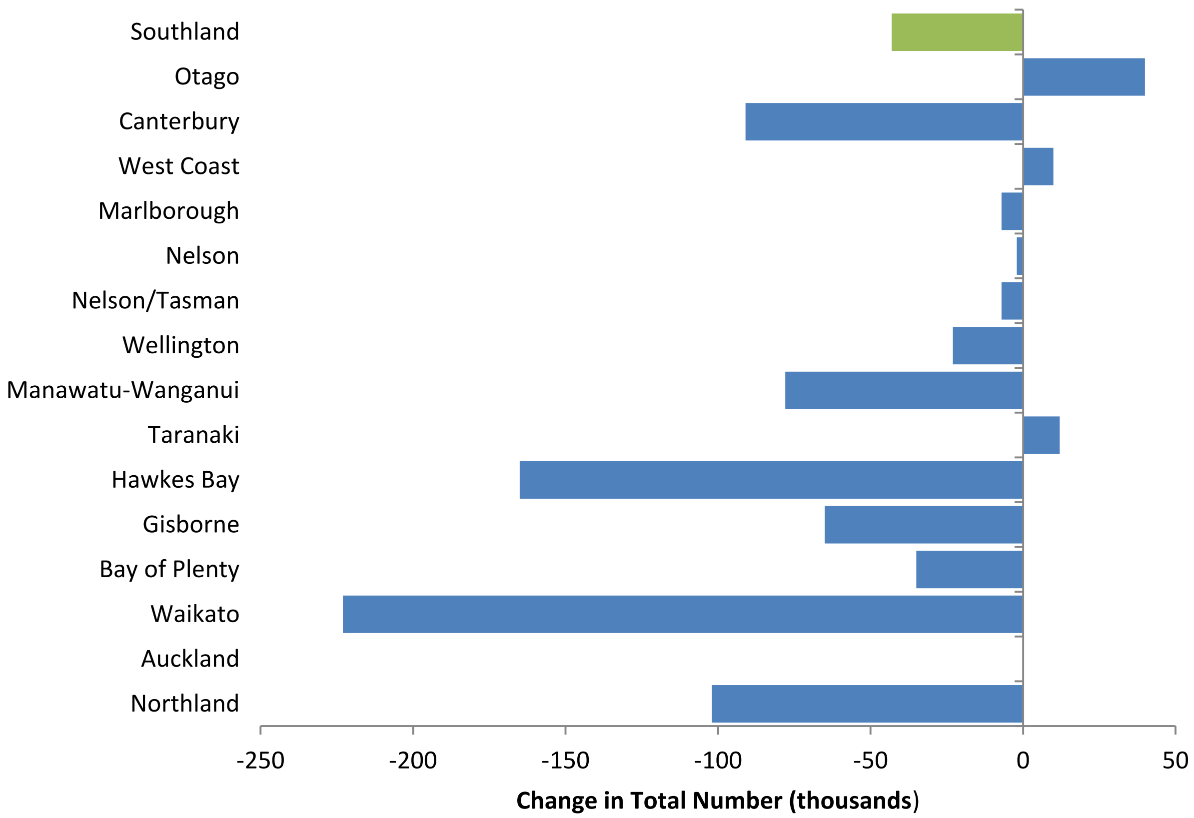

Figure B9: Change in beef cattle numbers by region 2004-2014
Source: Statistics New Zealand Agriculture Production Statistics

2.2. Main Features Specific to Southland

Sheep and beef farming in Southland has a number of important features. First, the ratio of sheep to beef cattle is much higher than in other regions at around ten sheep to one cattle beast. This ratio reflects how farmers have adapted to their local environment – environmental conditions such as soils, topography, climate, and so pasture production – and financial aspects of their businesses. Generally, sheep are better suited to Southland's environmental conditions than beef cattle.

The B+LNZ Sheep and Beef Farm Survey[35] classifies commercial sheep and beef cattle farms into eight farm classes – that are divided across the South Island and North Island and by relative intensity. 'Intensity' is defined using a combination of land type and appropriate farm management and it is a relative term within the sheep and beef industry (i.e. it does not necessarily imply that a particular farm class is an intensive land use). More information on the B+LNZ Farm Survey is included in Appendix 2 at the end of this report. Of the eight farm classes, four are relevant to Southland (they are highlighted below in green)[36]:

Class 1: South Island High Country – Extensive run country at high altitude carrying fine wool sheep, with wool as the main source of revenue. This farm class is located mainly in Marlborough, Canterbury and Otago.

Class 2: South Island Hill Country – Mainly mid-micron wool sheep mostly carrying between two and seven SU/eff.ha. Three quarters of the stock units carried over winter are sheep and one quarter beef cattle.

Class 3: North Island Hard Hill Country – Steep hill country or low fertility soils with most farms carrying six to ten SU/eff.ha. While some stock are finished a large share are sold in store condition.

Class 4: North Island Hill Country – Easier hill country or higher fertility soils than Class 3. Mostly carrying between seven and 13 SU/eff.ha. A high proportion of sale stock sold is in forward store or prime condition.

Class 5: North Island Intensive Finishing Farms – Easy contour land with the potential for high production. Mostly carrying between eight and fifteen SU/eff.ha. A high proportion of stock is sent to slaughter and replacements are often bought in.

Class 6: South Island Finishing-Breeding Farms – A more extensive type of finishing farm, also encompassing some irrigation units and frequently with some cash cropping. Carrying capacity ranges from six to eleven SU/eff.ha on dryland farms, and over twelve SU/eff.ha on irrigated farms. Class 6 is the dominant farm class in the South Island, but it mainly occurs in Canterbury and Otago.

Class 7: South Island Intensive Finishing Farms – High producing grassland farms carrying ten to fourteen SU/eff.ha, with some cash crop. Class 7 is located mainly in Southland, South and West Otago.

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[35] http://www.beeflambnz.com/information/on-farm-data-and-industry-production/sheep-beef-farm-survey/

[36] B+LNZ Farm Classes differ from LUC Class because they take into account the farm management, which means managing the physical (land, labour, livestock and other physical characteristics) and financial resources that make up the farm business, and income sources, whereas LUC Class is about the physical capability of the land (hence Land Use Capability), even though the two are numbered similarly (from 1 to 8)".

Class 8: South Island Mixed Cropping and Finishing Farms – A high proportion of revenue is derived from grain and small seed production as well as stock finishing. This farm class is located mainly on the Canterbury Plains.

Within Southland, sheep and beef farming is carried out on all land types, climate zones, and topographies and there are considerable differences in farm size. There are a handful of large high country stations (Farm Class 1) of 5,000 effective hectares and above, and tens of thousands of stock units. The high country farms have an average stocking rate of 1.3 SU/eff.ha. There are around 1,140 intensive finishing farms (Farm Class 7), the vast majority of which are on the Southland Plains. These farms have an average effective area of around 230 hectares and carrying roughly 2,700 stock units, but some are much smaller – around 100 effective hectares with roughly 1,000 stock units. The intensive finishing farms have an average stocking rate of 11.9 SU/eff.ha.

In total there are approximately 1,325 sheep and beef farms in Southland (each farm is the farm business and may include more than one property) and the majority (86%) are intensive finishing farms (Farm Class 7). Figure B10 shows the estimated distribution of commercial sheep and beef farms across New Zealand by farm class[37].

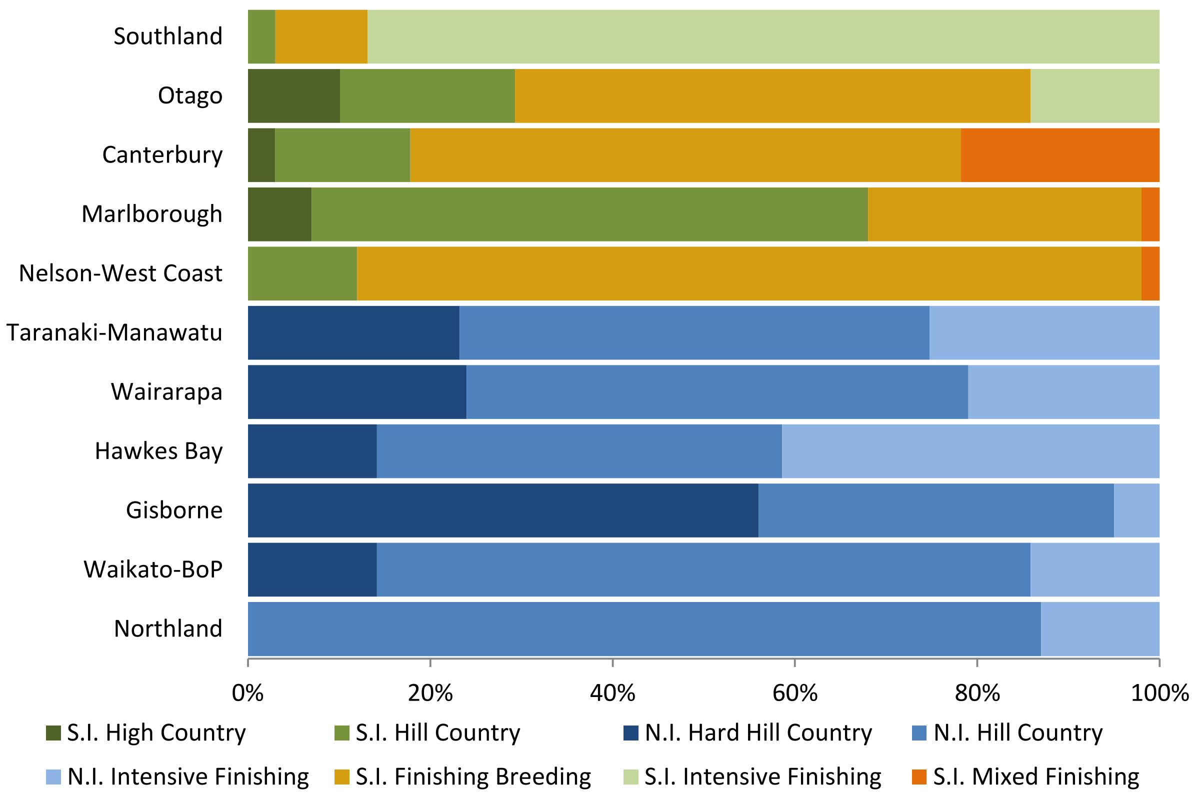

Figure B10: Percentage of farms by farm class and region 2013-14
Source: B+LNZ Economic Service, Statistics New Zealand

[37] B+LNZ estimates in collaboration with Statistics New Zealand, which produces New Zealand's official agriculture statistics from the Agriculture Production Census and Survey ("APC" and "APS" respectively).

Table B1 shows the main physical and production characteristics for New Zealand sheep and beef farms. This information underlines the diversity in areas and stocking rates between the different farm classes relevant in Southland. Many sheep and beef farms in Southland also carry deer.

Table B1: Average physical and production statistics for farm classes that occur in Southland 2013-14

Physical and production statistics		Class 1: South Island High Country	Class 2: South Island Hill Country	Class 6: South Island Finishing Breeding	Class 7: South Island Intensive Finishing
Farms in Sample	**No.**	23	37	100	33
Total Farm Area	**Ha**	8,821	1,744	493	252
Effective Area	**Ha**	7,929	1,496	430	230
Labour Units	**Full time equivalent (FTE)**	2.84	1.98	1.63	1.32
Sheep	**No.**	8,593	4,644	2,678	2,714
Cattle	**No.**	555	464	284	51
Deer	**No.**	169	88	36	7
Goats	**No.**	0	9	0	1
Sheep to Cattle Ratio	**No.**	15:1	10:1	9:1	53:1
Sheep	**SU (stock units)**	7,481	4,247	2,442	2,506
Cattle	**SU**	2,193	2,158	1,039	222
Deer	**SU**	289	145	61	12
Goat	**SU**	0	6	0	1
Total	**SU**	9,963	6,556	3,542	2,741
Stocking Rate	**SU/eff.ha**	1.3	4.4	8.2	11.9
Lambing Performance	**%**	101.3%	123.0%	131.9%	141.5%
Calving Performance	**%**	80.1%	84.6%	89.1%	100.0%
Wool Sold	**kg/sheep at open**	4.07	4.19	4.54	5.05
Wool Sold	**kg**	34,958	19,481	12,153	13,702
Wool Sold	**kg/eff/ha**	4.4	13.0	28.3	59.6
Lambs Sold	**No.**	2,468	3,111	2,184	2,525
Sheep Sold	**No.**	2,112	995	622	658
Cattle Sold	**No.**	204	177	95	18
Deer Sold	**No.**	75	35	20	3
Goats Sold	**No.**	0	12	0	0

Source: B+LNZ Economic Service Sheep and Beef Farm Survey

2.3. Profitability

Like all industries, profitability in sheep and beef farming has fluctuated over time. It weakened during the 1980s and 1990s following deregulation, and improved in the early 2000s as depreciation of the New Zealand dollar boosted revenue. Subsequent fluctuations have occurred as the result of the volatility of product prices and seasonal conditions, which impact on productivity. Fluctuations in prices over time for products from sheep (i.e. meat and wool) have a larger effect in Southland compared to other regions because of the higher proportion of sheep to cattle. Similarly, fluctuations in prices for beef, and so cattle, products are less readily felt in Southland.

In general, Southland sheep and beef farms have been more profitable than the New Zealand average. Figure B11 shows inflation-adjusted profitability (using real farm profit before tax – with 'real' meaning it is adjusted for inflation) for Southland farms compared with New Zealand between 1990 and 2014. The gap between the two lines largely reflects the dominance of sheep in Southland, which means that the region benefits more from returns for the joint products of wool and lamb/mutton than returns from beef products. As the amount of land being used for intensive finishing farming has contracted in Southland, the industry has become reliant on the performance of hill and high country farming.

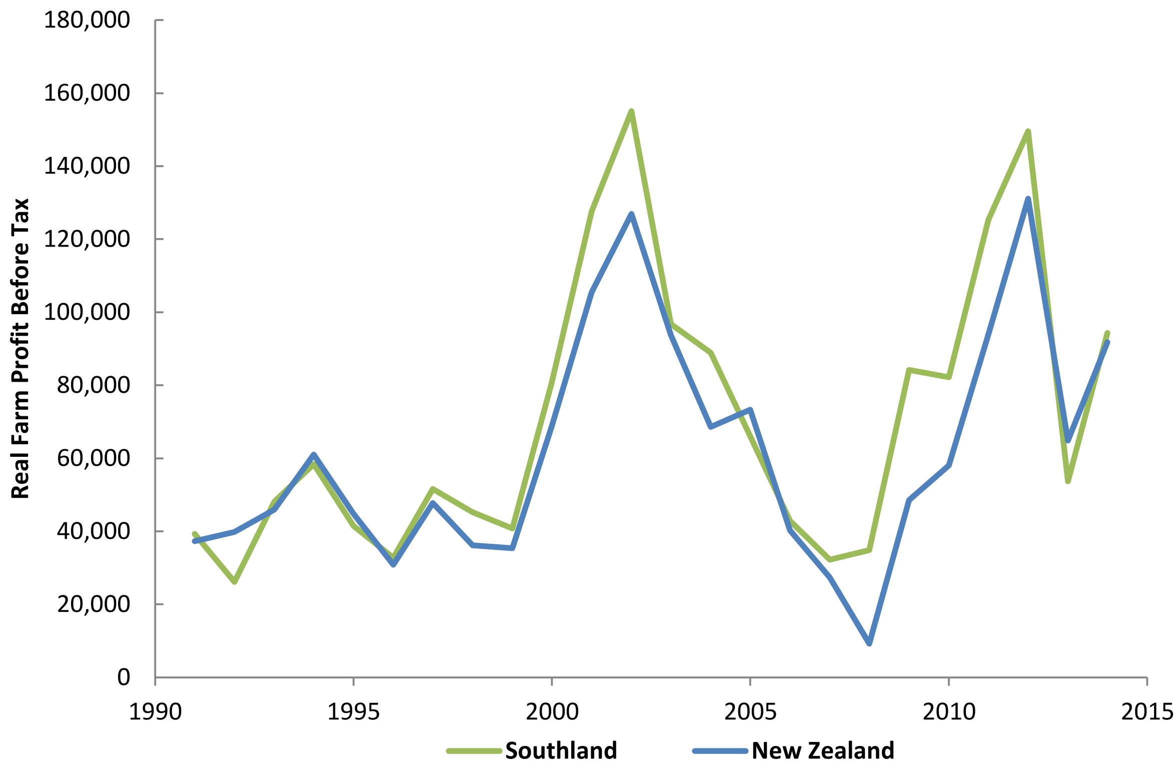

Figure B11: Sheep and beef farm profitability for Southland and New Zealand (year to June) 1991-2015
Source: B+LNZ Economic Service Sheep and Beef Farm Survey

Per-farm measures do not take into account farm size, which for sheep and beef farms varies considerably. The use of 'per hectare' allows a more consistent comparison between farms that are of different sizes. It is an industry convention to use a farm's effective area for such calculations. Figure B12 shows the financial performance for Southland and for New Zealand as a whole on a per effective hectare basis (using inflation-adjusted Earnings before Interest Tax and Rent (EBITR)). On this basis, the gap in profitability between Southland and New Zealand is much wider on a per hectare basis than by farm and possibly has been becoming more so over time.

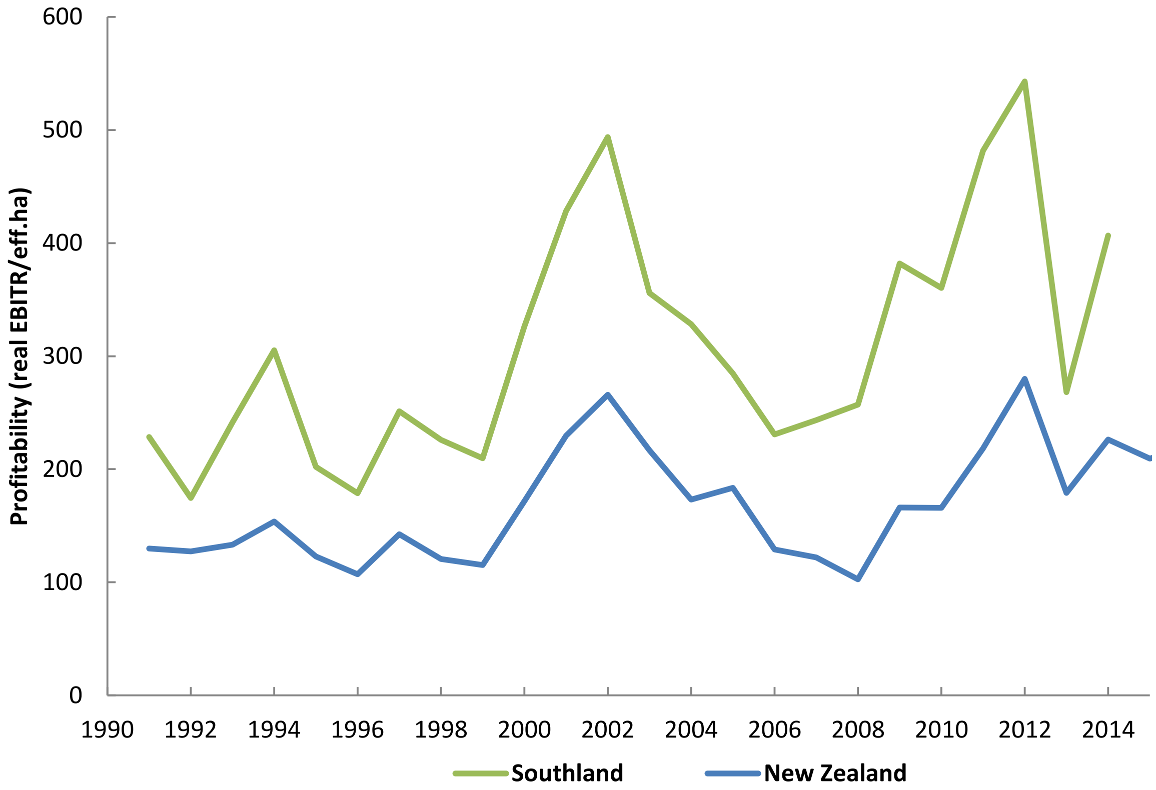

Figure B12: Sheep and beef farm profitability for Southland and New Zealand (year to June) 1991-2014
Source: B+LNZ Economic Service Sheep and Beef Farm Survey

2.4. Productivity and Production

Following deregulation of the New Zealand economy in the mid-1980s, the sheep and beef industry consolidated. In general, the number of sheep and beef cattle and farms declined while the average farm area and average number of livestock (measured by stock units) on the remaining farms increased. Since the 1980s there has been a steady rise in lamb and beef prices, and gradual increases in both intensity and productivity on-farm, as farmers responded to market signals that reward them for meeting specifications relating to both the product and its timing. Although there has been some variability in lamb, wool, and beef prices, it is less than for dairy, and the diversity of these product streams further helps farmers manage risk. Sheep and beef farmers have focused their attention on improving productivity, through genetics and the use of inputs such as fertiliser[38]. Table B2 shows changes in key measures for sheep and beef farms between 1990 and 2013.

[38] Fertiliser use and expenditure on grazing are reported for Farm Class 7 South Island Intensive Finishing Farms, with an estimated 87 percent of Farm Class 7 South Island Intensive Finishing farms being in Southland.

Table B2: Key metrics for sheep and beef farms in Southland

Key metrics	1990-91	2013-14	% Change between time periods
Sheep and Beef Farms* (number)	3,190	1,325	-58%
Stocking Rate (SU/farm)**	2,580	2,970	+15%
Effective Area (ha/farm)**	293	316	+8%
Stocking Rate (SU/eff.ha)**	8.8	9.4	+7%
Total Fertiliser Use (kg/eff.ha)	90	201	+123%

Source: B+LNZ Economic Service Sheep and Beef Farm Survey
*Commercial farms **Weighted average across farm classes

A key indicator of productivity improvements is the change in lambing performance over time. Although individual and average lambing percentages vary between years because of climatic differences (e.g. a severe snowstorm in September 2010), sheep and beef farms in Southland produced, on average, around 20 more lambs per 100 ewes in 2013-14 than in 1990-91. Figure B13 shows lambing performance from 1990-91 to 2013-14. Profitability depends on the combination of a number of factors, such as lamb weights, livestock growth rates, livestock losses, and expenditure. With the late start to the growing season, the period from weaning to selling lambs off-farm is critical to success in Southland. Growing lambs quickly for sale means that more feed can be put into ewe weights for mating, which can increase lambing percentages. No single factor drives profitability, and other factors, such as limiting livestock losses, are also important.

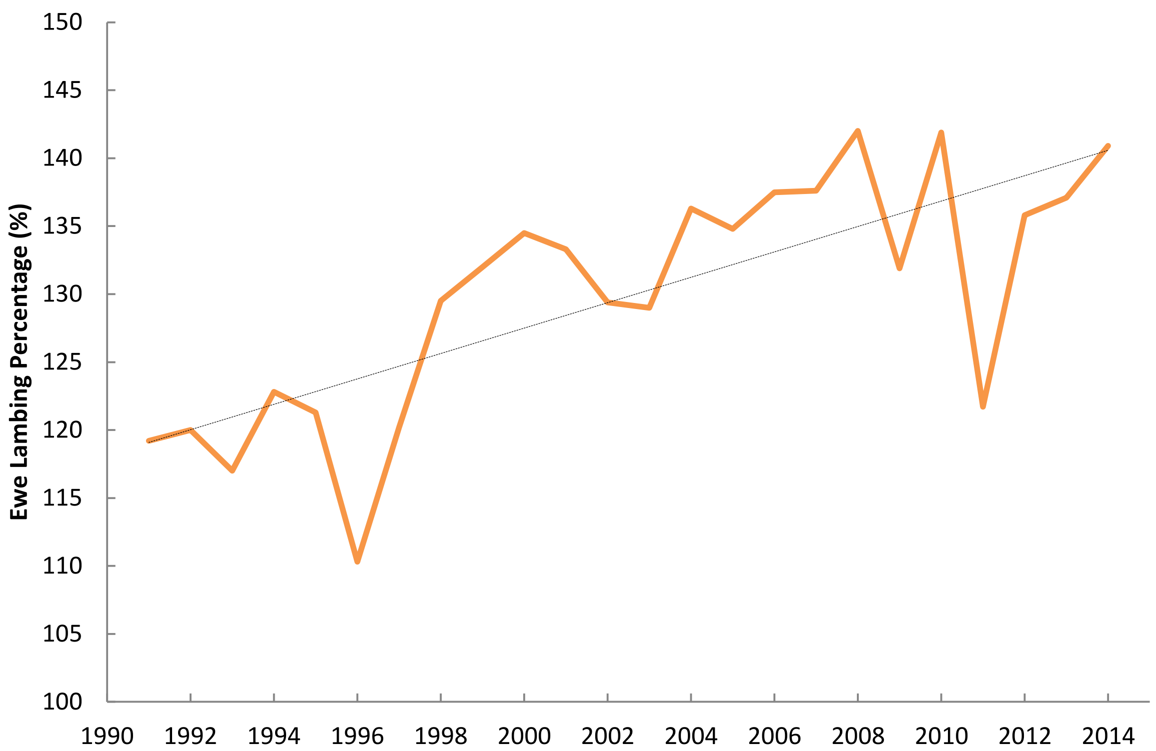

Figure B13: Lambing percentages for Southland (year end June) 1991-2014
Source: B+LNZ Economic Service Sheep and Beef Farm Survey

A sheep and beef farm grows a complex mix of products but it predominantly produces meat. Since the 1990s, total net meat production per hectare for lamb and beef has been continually improving. Compared to the weighted average for all farm classes for New Zealand, South Island Intensive Finishing farms (Farm Class 7) are heavily weighted towards growing lamb, compared to beef, and are highly productive. Production and productivity do not necessarily equate to profitability. The most profitable farmers tend to be those that are skilled at adapting their farming system to the local environment and achieving their objectives, rather than working to maximise one aspect of their business.

Farm stocking rates vary because of a range of production and financial factors. In 1990-91, most farms carried between 13 and 15 SU/eff.ha but by 2013-14 the distribution was wider with most farms carrying between 9 and 14 SU/eff.ha. Productivity (as indicated by increased lambing percentages) improved during this period and the capital livestock on farms reduced. The more recent profitability of dairy farming resulted in productive land being sold for dairy conversions, which pushed drystock farming onto less productive areas. Large areas of some farms also became part of the conservation estate managed by the Department of Conservation as a result of tenure review. Figure B14 shows an estimated of the distribution of stocking rates on farms in Southland (using SU/eff.ha).

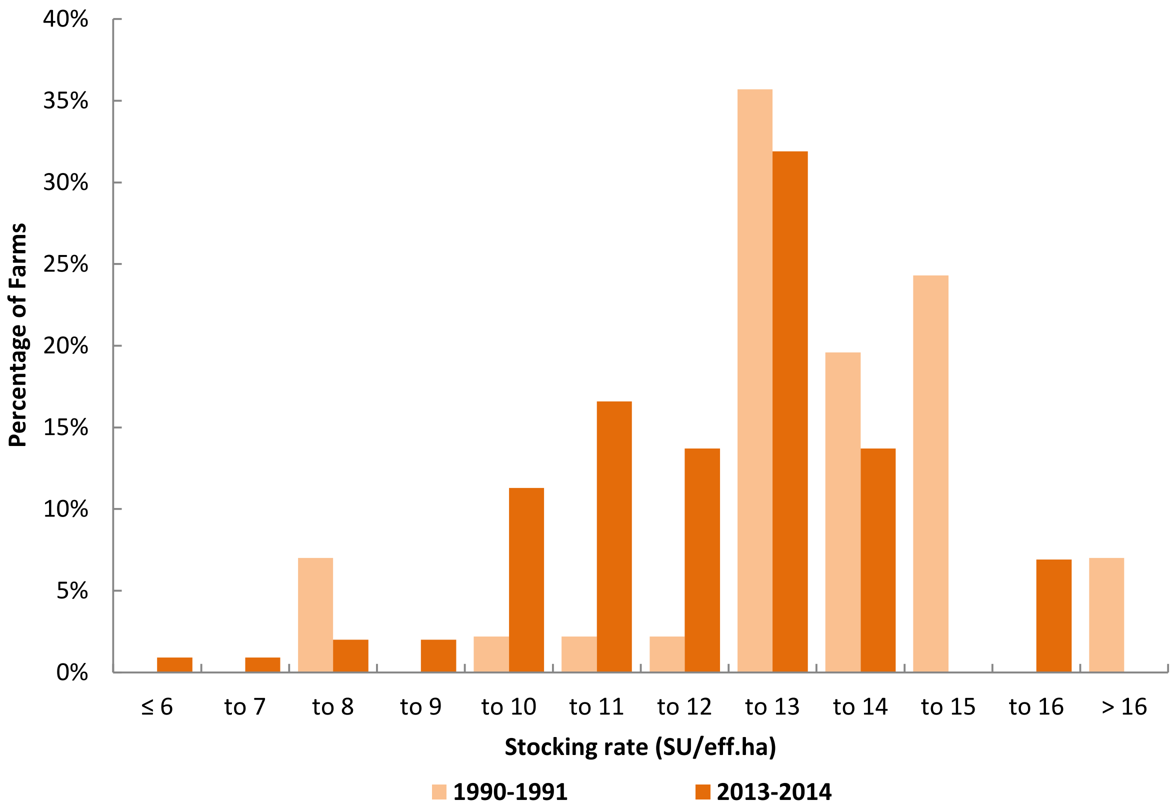

Figure B14: Distribution of stocking rates per farm for Southland
Source: B+LNZ Economic Service Sheep and Beef Farm Survey

Over the past 30 years, fertiliser use (nitrogen and phosphorus) on South Island Intensive Finishing farms (Farm Class 7) has varied. It declined markedly during the 1980s, as farmers adjusted to deregulation of the industry when low product prices impacted negatively on cash flow and farmers' ability to pay for inputs. The use of phosphorus fertiliser had returned to pre-deregulation levels by 1995, and rose to a peak in 2002, before falling back to 1995 levels over the course of the next decade. Recorded nitrogen fertiliser use on sheep and beef farms started in Southland in the 1980s and has been gradually increasing since the early 1990s. Much of the variability comes from changes in fertiliser expenditure in low-input systems. Farmers' decisions about fertiliser are determined by a complex mix of soil fertility, fertiliser prices, production objectives, and revenue considerations. Figure B15 shows fertiliser applications measured in elemental components of nitrogen and phosphorus (i.e. without the 'filler' used to deliver it) from 1984 to 2014.

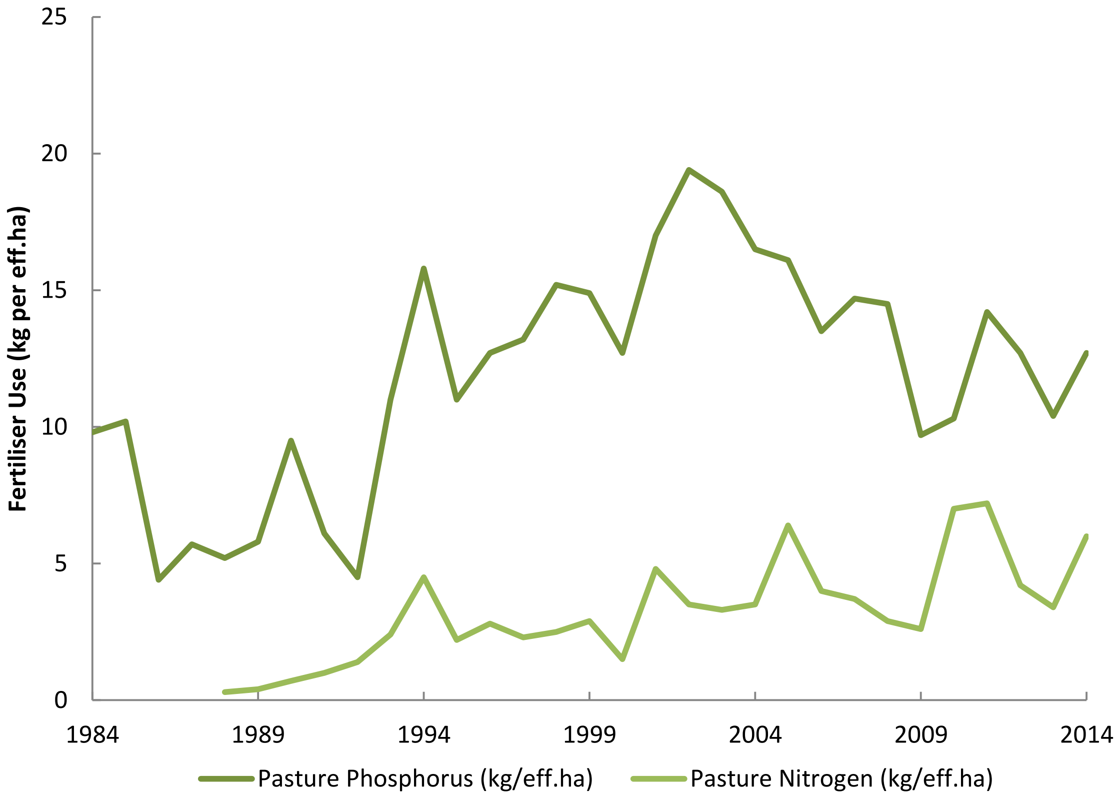

Figure B15: Nitrogen and phosphorus pasture fertiliser applications in Southland (year end June)
Source: B+LNZ Economic Service Sheep and Beef Farm Survey

In New Zealand sheep and beef farming systems have adapted to meet the natural pasture growth curve. This adaptation accounts for variations between stock classes, farm types and mixes throughout Southland and between Southland and other regions. Some farming systems also use technology to shift and/or extend the pasture growth curve and to produce animals that can make the best use of that feed. This strategy is low-cost, and generally, low-risk.

Feed is not 'imported' onto sheep and beef farms in the way it often is on dairy farms, although some farmers pay for grazing. Almost all feed consumed is produced on-farm. Generally, nine out of ten South Island intensive finishing farms, which are 86% of the sheep and beef farms in

Southland, spend at least $16 per hectare to conserve feed from peak pasture growth or grazing[39] as silage or baleage (compared with two-thirds of all sheep and beef farms in New Zealand). This expenditure reflects Southland's shorter growing season and means the winter feed area of a farm is particularly important. Figure B16 shows that roughly 80 percent of South Island intensive finishing farms had a winter feed area in 2013-14 equivalent to 2-8 percent of the farm's effective area, and a handful of South Island Intensive Finishing farms had a winter feed area ten percent or above.

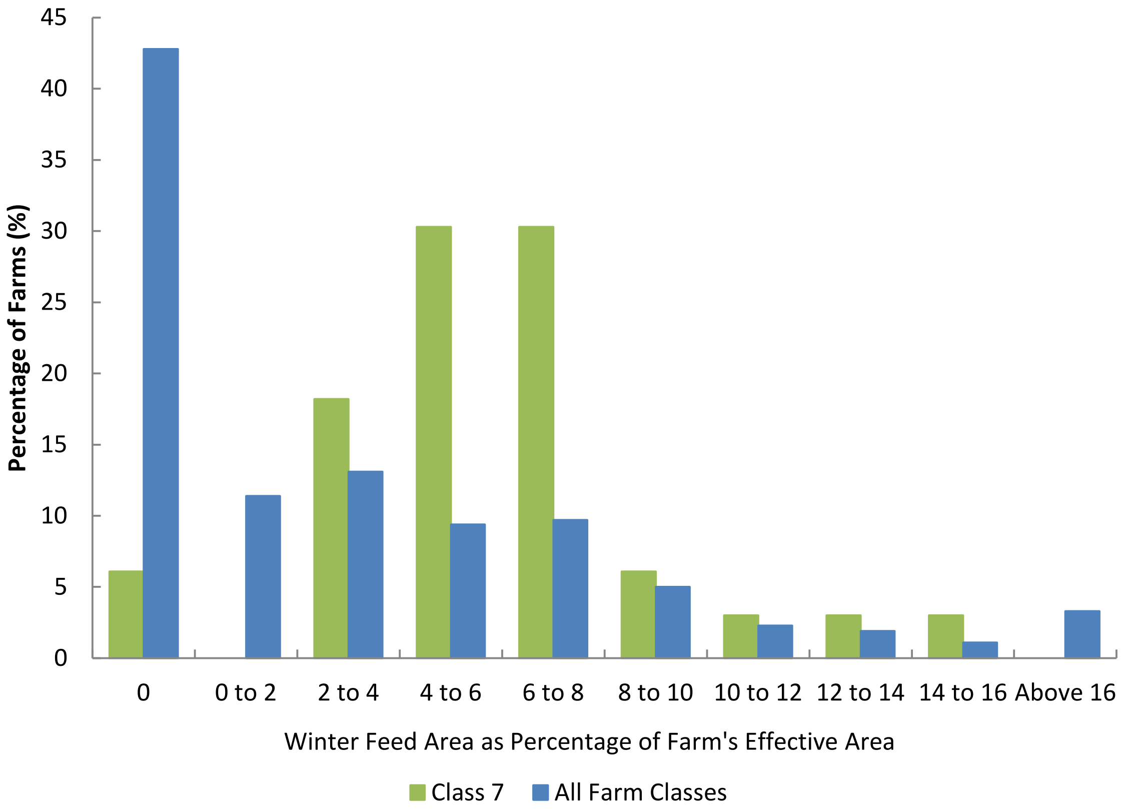

Figure B16: Distribution winter feed area for Class 7 and all farm classes in New Zealand
Source: B+LNZ Economic Service Sheep and Beef Farm Survey

In Southland around one quarter of sheep and beef farms earn revenue from dairy grazing, which is lower than the national average. Dairy grazing is a term that is often used loosely – sometimes for the grazing of dairy heifers for a whole season, sometimes for the short-term grazing of dairy cows between seasons (after drying off at the end of one season and before production resumes on the milking platform), and sometimes a combination of both. However, dairy grazing is specifically about grazing dairy cows, where it is an important and regular feature of the farm business, and it includes the regular annual grazing of dairy cows for an extended period through winter. In addition to dairy grazing, fewer than ten percent of sheep and beef farms in the region receive revenue from casual grazing, which is the short–term or ad hoc grazing of dairy cattle or other livestock (i.e. during the weeks between milking seasons).

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[39] Feed and grazing includes costs for making and transporting hay and silage (including by contractors) in addition to purchases of grazing and feed that is brought onto a farm.

2.5. Seasonality

Pasture growth in Southland is generally more variable across the year than in other parts of New Zealand, and is largely driven by the region's climatic conditions. The seasonality in pasture growth carries through to slaughter patterns and meat production in Southland. The lambing period in Southland follows the pasture growth curve, usually starts in early September and peaks in the first week of October. Pasture growth begins in earnest later, and from a lower level, than in other regions, and reflects the cool, wet climatic conditions in spring. By comparison, lambing in the North Island usually starts at the end of July/start of August and peaks in mid-September.

The shorter pasture-growing period and later lambing in Southland carry through to the processing of livestock. For lamb, the processing season in the South Island is shorter, rises more rapidly to a peak, and is more variable than in the North Island, where the number processed at peak-season is lower but the number processed in the 'off-season' is higher. For adult sheep (mutton), peak processing is usually reached in January but can vary according to the availability of processing space, which often depends on the number of lambs being processed. For adult cattle, fewer overall stock are processed in the South Island, but both South and North Islands have similar seasonal variability. The peak processing month is usually May, boosted by the cows culled from dairy herds at the end of milking, but it can occur earlier in a dry year.

2.6. Meat Processing and Markets

The sheep and beef industry importance to Southland is in the value the industry adds to the economy and the jobs it creates. When combined with meat processing, the industry is the largest employer in Southland. In addition, Southland's sheep and beef industry is important nationally. The region contains about 15 percent of New Zealand's sheep, and five percent of New Zealand's beef cattle. New Zealand's drystock industries focus on producing livestock that are processed into meat and meat products for export. Table B3 shows over 90 percent of lamb and mutton, and 80 percent of beef production is exported. Consequently, New Zealand's meat processors and exporters, and their suppliers of livestock, rely heavily on exporting to a wide range of markets.

Table B3: Share of New Zealand pastoral products exported (year end June) 2014-15

Product	Export share	Export value ($ millions)
Wool	91%	$805
Lamb*	92%	$2,753
Mutton*	94%	$568
Beef and Veal*	80%	$3,555
Deer [$244m] + Other	96%	$877
Total		**$8,558**

* Includes co-products
Source: B+LNZ Economic Service, Statistics New Zealand

The three companies in New Zealand with the largest quota allocations for sheep and goat meat to the European Union and beef and veal to the United States all have processing plants in Southland:

Alliance Group Ltd., Silver Fern Farms Ltd., and AFFCO New Zealand Ltd. These tariff rate quota allocations indicate production volumes of New Zealand meat processors. Table B4 shows the tariff rate quota allocations for companies with a plant in Southland. In total, these companies account for 68.6 percent of the quota allocations for the European Union, and 56.6 percent of the quota allocations for the United States. Southland-based meat processing companies are some of the largest in New Zealand, and some of the largest producers of lamb in the world. They are major contributors to New Zealand's lamb exports. The pattern of sheep and beef exports from Southland is similar to the pattern for New Zealand as a whole.

Table B4: Tariff rate quota allocations for companies with a processing plant in Southland for 2015

	European Union sheep and goat meat		United States beef and veal meat	
	Tonnes	**Share of NZ total**	**Tonnes**	**Share of NZ total**
Alliance Group Ltd.	65,303	28.7%	18,855	8.8%
Silver Fern Farms Ltd.	53,537	23.5%	63,612	29.8%
AFFCO New Zealand Ltd.	28,729	12.6%	37,186	17.4%
Blue Sky Meats Ltd.	6,537	2.9%	289	0.1%
Prime Range Meats Ltd.	2,157	0.9%	885	0.4%
Total	**156,263**	**68.6%**	**120,827**	**56.6%**

Source: New Zealand Meat Board

Alliance Group Limited (AGL) is based in Invercargill and is a co-operative, wholly owned by around 5,000 farmers. It is one of the world's largest processors of sheep meat and New Zealand's largest producer of lamb. Alliance Group has a turnover of around $1.5 billion, and two large meat processing plants in Southland – at Lorneville and Matāura.

Silver Fern Farms Limited (SFF) is based in Dunedin. Its origins are as a farmer-controlled co-operative, representing more than 16,000 sheep, cattle and deer farmer-shareholders throughout New Zealand. Silver Fern Farms is the largest livestock processing entity in New Zealand, employing around 7,000 people at the peak season. Its annual turnover exceeds $2 billion, and it operates plants at Kennington, Mossburn and Waitane in Southland.

South Pacific Meats Limited Invercargill (SPM) operates a processing plant at Awarua and is owned by AFFCO New Zealand Limited, which is a member of the Talley's group of companies and is wholly owned by the Talley family.

There are two other companies operating in Southland that process and export smaller volumes of meat. **Blue Sky Meats (NZ) Limited (BSM)** is a privately held firm with two processing plants in Southland (at Morton Mains and Gore). **Prime Range Meats Limited (Prime Range**) is a privately held firm with a majority shareholder based in China and a processing plant at Invercargill.

New Zealand exports lamb to nearly 100 countries with some key export markets (Table B5). In 2014-15, the United Kingdom, China, United States, Germany and the Netherlands accounted for two-thirds of total value and total volume. The United Kingdom is a longstanding market for New Zealand lamb and the largest single country market by value. The United States and China are becoming increasingly important but there is a large difference in the value of the products (measured in $ per tonne) between the two markets. China moved up from eighth most important market by value in 2007-08 to second in 2013-14. It has traditionally had lower value cuts but more recently higher value cuts (e.g. shoulders and legs) are beginning to feature, reflecting new growth opportunities. China was the largest single country market by volume in 2014-15, with 29 percent of the tonnage, followed by the United Kingdom with 20 percent. The United States was the third most important market by value in 2014-15, and is focused on high value cuts such as lamb racks.

Table B5: Key New Zealand lamb export markets (year end September)

	2007-08	2013-14	2014-15	2014-15 $ 000	2014-15 $ per tonne	Change 2013-14 to 2014-15
1	UK	UK	UK	525,851	8,797	-1.3%
2	Germany	China	China	459,093	5,285	-2.4%
3	France	USA	USA	257,538	13,172	6.2%
4	USA	Germany	Germany	234,211	12,886	-1.4%
5	Belgium	Netherlands	Netherlands	169,807	12,902	-1.6%
6	Canada	France	France	129,007	9,914	-3.6%
7	Saudi Arabia	Saudi Arabia	Saudi Arabia	110,044	6,661	0.2%
8	China	Canada	Canada	88,728	9,618	7.5%

Source: B+LNZ Economic Service, New Zealand Meat Board

The United States and China are also key markets for beef exports (Table B6). New Zealand has a long history of supplying lean beef to the US, primarily for the production of ground beef. Americans consume the majority of their beef in ground beef form. Frozen New Zealand beef provides a valuable ingredient because, among other things, it is consistent, production is reliable, it has superior food safety credentials, and has well-established supply chains and distributions systems. China was New Zealand's second largest market by value for 2014-15. Volumes have lifted from less than 500 tonnes in 2007-08, to 61,283 tonnes for 2014-15, reflecting a large increase in demand for lower value cuts. Meat processors and exporters produce and export a wide range of items, including hides and skins, tallow and offal, that contribute to New Zealand's merchandise exports.

Table B6: Key New Zealand beef and veal export markets (year end September)

	2007-08	2013-14	2014-15	2014-15 $ 000	2014-15 $ per tonne	Change 2013-14 to 2014-15
1	USA	USA	USA	1,652,684	7,205	33.9%
2	South Korea	China	China	420,190	6,857	23.4%
3	Japan	Japan	Taiwan	174,340	8,015	17.2%
4	Taiwan	Taiwan	Japan	156,043	8,657	30.8%
5	Indonesia	South Korea	Canada	129,781	6,793	27.8%
6	Canada	Indonesia	South Korea	109,468	5,674	4.3%
7	UK	Canada	Netherlands	45,105	16,544	15.7%
8	French Polynesia	Hong Kong	Indonesia	44,317	6,342	28.5%

Source: B+LNZ Economic Service, New Zealand Meat Board

2.7. Future Outlook

Farmers, processors, exporters and others in the value chain have been adapting to new circumstances for over a century, as market signals and incentives change, and they strive to meet customer demand. A key factor in the future will be whether it is possible to maintain flexibility within farming to be able to continue adapting while achieving a community's goals, of which farmers are a part.

Image B3: Beef cattle near the Te Anau Basin
Source: Simon Moran

Southland sheep and beef farmers produce the raw material for a wide range of products, which are exported to customers around the world. Consequently, its future outlook is relatively dependent on export markets, some of which are going through a period of transition. Demand continues to grow for well-produced items, which goes wider than the physical product to include all of the added value from processing and reliably delivering the product to those customers. Such items require on-going investment in the value chain and relationships between a wide range of participants. Sheep and beef farming systems have responded well over the years to changing circumstances, while managing many risks. Some risks are fully under the control of the farmer and some can be managed but are not fully controlled by the farmer.

2.8. Environmental Issues Linked to Water Quality

The sheep and beef industry is characterised by a range of farm system types, determined in large part by the soils and slope of the land and the climate. Over the past 30 years, large productivity gains have been achieved, particularly through genetics and improving feed quality. These gains are mostly seen in the hill country, extensive farming with breeding, pasture improvement and opportunities to diversify. In more recent times, fluctuations in returns across the industry have led to farming businesses increasingly diversifying. For example, a portion of the farm is used for dairy support, or the stock profile is changed to increase the ratio of beef cattle. It is in this broader setting that the environmental risks on sheep and beef farms are considered here.

Sheep behaviour is such that they generally avoid access to water bodies, except during hot weather or to access feed on the other side. There is some evidence that stock camping adjacent to some water bodies can lead to increased levels of microbes after rain and elevated water levels. Sheep access to water is also linked with sediment and phosphorus issues, particularly where they have established a track to/from a water body, and also around culverts and bridges. Beef cattle and dairy cattle are similar to each other in their need for drinking water, and their comfort in accessing and standing in water bodies. These natural behaviours can result in the direct deposition of microbes, as well as sediment and phosphorus losses. The relative contribution of all of these substances tends to be greater than from sheep because of cattle's size and their comfort in entering water.

Other activities, such as cultivation (conventional or minimum till methods), application of fertiliser, and land development to lift a farm's carrying capacity, can all generate the release of sediment, phosphorus and, to a lesser extent, microbes. Adapting and applying good management practices to suit the land, farming practices and business requirements has been shown to minimise these losses to a greater extent.

Turning to nitrogen, the profile of sheep and beef farms paints an interesting picture. Nitrogen losses from an extensive property with predominantly sheep and some beef cattle is generally low because of both the lower concentrations of nitrogen in sheep urine and the large area of the farm. When a farm business is diversified (e.g. into an increased ratio of beef cattle, or into the raising or grazing of dairy cattle), or an 'intensive finishing block' is further intensified, it is likely that nitrogen losses may rise to the level of lower intensity dairy farming operations. Where these activities are undertaken on free draining soils and/or in an area of high rainfall, further nitrogen losses may occur. So while nitrogen losses are typically low from a sheep and beef farm, it should not be assumed that they are always low.

Overall, phosphorus and sediment losses tend to be the greatest environmental risk. Nitrogen loss is likely to be a challenge for farmers who farm more intensively and want to either lift productivity dramatically or shift away from their existing production systems. The sheep and beef industry has an array of good management practices through B+LNZ's Land and Environment Plans[40] that can be adapted to suit different farming systems and settings. There is a lot to be positive about in terms of the industry adapting to better manage its environmental footprint into the future.

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[40] http://www.beeflambnz.com/lep

3. Deer Farming

Authors: Lindsay Fung (Environmental Policy Manager), Tony Pearse (Producer Manager), **Deer Industry New Zealand.**

Deer farming is generally located on the Southland Plains or the high country areas in northern and western Southland, as shown in Figure B17. There is a concentration of large farms in the Te Anau Basin and a large number of specialist deer properties occur in and around the Invercargill area. As deer farming is based on the annual production of meat and other animal products it shares many similarities with sheep and beef farming. A deer farm is usually run as either a specialised deer farm or as a part of a mixed drystock farm. Deer have different seasonal feed requirements to sheep and beef and the three stock types are often seen as complementary, despite the investment needed for deer fencing.

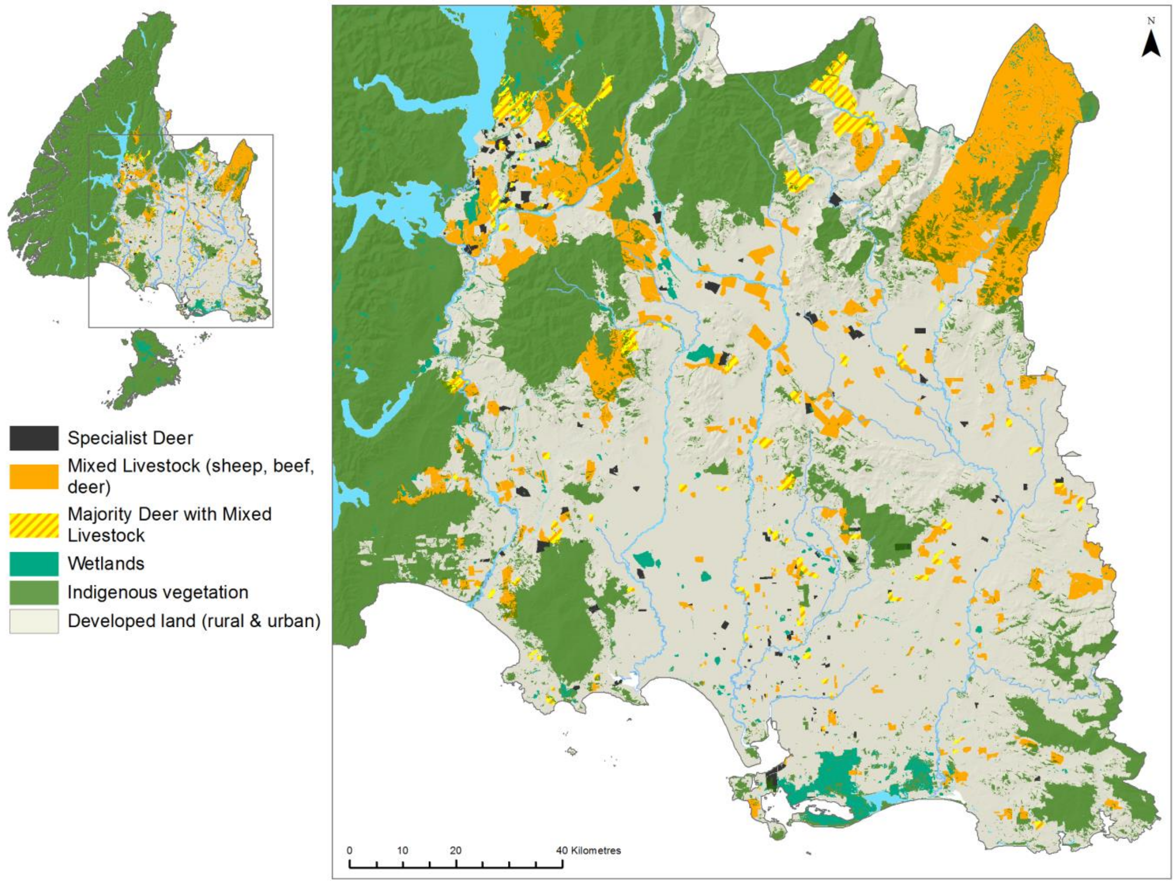

Figure B17: Deer farming in Southland 2015
Source: Pearson and Couldrey (2016)

In total, deer farming covers around 270,000 hectares of land over 456 properties. Following advice from Deer Industry New Zealand (DINZ), deer properties were categorised for the Southland Land Use Map as: specialist deer (100% deer), mixed deer (>45% deer), mixed sheep, beef and deer (<45% deer). Table B7 shows the distribution of deer properties in Southland by freshwater management unit (FMU) using these categories (for more information on FMUs refer to Part A: Section 1.4).

Table B7: Distribution of deer properties in Southland

FMU	Total area (ha)	Number of Properties	Average area (ha)
Specialist Deer Total	**15,311**	**170**	**90**
Matāura	3,928	32	123
Ōreti	5,359	71	75
Aparima	1,637	15	109
Waiau	4,365	50	87
Fiordland & Islands	22	2	11
Mixed Deer Total	**31,385**	**38**	**826**
Matāura	10,890	9	1,210
Ōreti	8,695	14	621
Aparima	1,098	4	275
Waiau	10,702	11	973
Mixed Sheep, Beef & Deer Total	**223,277**	**248**	**900**
Matāura	115,145	71	1622
Ōreti	28,789	86	335
Aparima	20,905	28	747
Waiau	58,437	63	928
Total for Southland	**269,973**	**456**	**592**

Source: Pearson and Couldrey (2016)

Over recent years, an increasing number of large sheep and beef farms in Southland have included deer in their farming mix. Most deer farms (estimated to be over 70%) are now mixed drystock operations – typically with sheep and/or beef cattle, but dairy grazing and cropping are also seen. Mixed drystock operations have expanded farmers' options for sustained profitability in red meat supply and are an alternative to traditional drystock farming. Deer farms previously tended to be focused on either breeding or finishing, but more recently there has been a shift towards both operations on the same farm.

3.1. History of Deer Farming in Southland

Deer farming is a relatively new industry, compared to other pastoral land uses[41]. Internationally, Southland is the pioneer region for large-scale commercial deer farming. Southland's deer industry currently has the second largest herd in New Zealand, and it is considered the most advanced, through the supply of high quality genetics, animal specialist support services, stock transportation and processing. Overall, the New Zealand deer industry is the largest and most advanced of its kind in the world.

[41] Before the 1970s deer were raised on aristocratic estates in Europe for hunting, or housed in small enclosures in Asia for velvet production.

The first deer farming licence was issued in Southland in 1970, and the New Zealand Deer Farmers Association was set up in 1975. The initial interest in deer farming was accentuated by an abundant supply of available stock, through wild deer capture, and an established wild venison recovery and processing industry.

Image B4: Velvet stags in the Matāura FMU
Source: Southland Deer Farmers Association

Since the New Zealand deer industry's peak in 2002, with 5,200 farmers and 2.1 million deer, it had contracted nationally by 2015 to 2,100 farmers and 950,000 deer. In Southland, the deer industry is more entrenched than in other regions, and is influenced by Landcorp Farming Ltd.'s large deer holdings in the Te Anau Basin. Beyond these corporate holdings, the farmers that remain in the industry are often from the pioneering deer farming families.

With its history, Southland quickly became the centre of New Zealand's commercial deer transportation and specialist venison processing plants. The deer industry's growth in the region continued with the entry of the large meat processing co-operatives, Alliance Group Ltd. and Silver Fern Farms. These two co-operatives concentrated the venison processing capacity for the lower half of the South Island in Southland. Southland's processing capacity is estimated to be roughly 40-45 percent of New Zealand venison, although current levels are around 35 percent.

The main deer species farmed in New Zealand are red deer, but over time other varieties and other species (e.g. wapiti and Eastern red deer) have been crossbred and are also farmed[42]. In Southland, access to nearby wapiti in Fiordland, has led to their crossbreeding with red deer.

The Southland deer industry is second only to Canterbury as the most important region for velvet production, both for volume and quality.

3.2. Farm Classes

Deer farms are usually classified in terms of production and they are a mix of venison, velvet, and/or trophy antler production systems. Although most farms are self-contained breeding and finishing units, there are also specialist operations concentrating on either breeding or finishing. The different mix of age classes in each production system presents different environmental risks on-farm because of the size and seasonal, sex or age-related behaviours of the deer (refer to Part B: Section 3.9). The main characteristics of these production systems are as follows:

Venison: Animals are typically slaughtered at 12-18 months of age. There will be a capital stock breeding herd of hinds, and a smaller group of selected breeding stags (older animals), which are used to provide animals for either slaughter or replacement.

Velvet: The focus is on stags that produce heavy antlers with a good configuration – stags are retained for many years as the antler weight grown each year increases with age[43]. There will be a selected breeding herd of hinds. Young female deer not needed for breeding and young males not being kept for velvet production, are either on-sold to other farms or processed for venison. Older breeding hinds and velvet stags are also culled for venison.

Stud: The focus is on establishing breeding lines of high genetic value for velvet (predominantly), venison or trophy antler markets. The progeny (offspring) of stags is sold to production farms or breeders, usually at 2-3 years of age for elite males, or at 12-20 months of age for elite females. Velvet and venison production also occur on the same farm.

Across the country, the deer industry's main focus is on venison production (roughly 80-85% of deer farms), and it is likely that a similar distribution is found in Southland. Table B8 outlines a deer production calendar that describes the main deer stock class activities and production systems throughout a year. It highlights the peak season for chilled venison from September to November (red on the calendar). The production calendar gives an indication of the complexity and diversity of deer farming. The traditional variation between peak and trough in venison prices is becoming less pronounced, possible because of increased exports to the United States, where there is not the same seasonal demand for game meat as Europe. The calendar just covers the activities of a deer production system – many deer farms also include sheep and/or beef enterprises, which introduce extra layers of complexity into the farming activities.

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[42] Wapiti freely interbreed with red deer and produce viable offspring. Wapiti and red deer have been considered as the same species (both with 68 chromosomes) until analysis of mitochondrial DNA resulted in classification to two different species. There are quite distinct morphological and physiological differences but are genetically compatible and only naturally separated by geography (Atlantic Ocean). For all practical purposes they are considered as the same species.

[43] Some farmers prefer not to keep stags in a herd for too long because aggression issues can arise between younger and older ones. It can be reduced by keeping stags within similar age ranges.

Table B8: Deer Production Calendar (peak venison price is from September to November)

Month	Adult breeding stags	Adult velvet stags	Yearling stags	Weaned adult hinds	Un-weaned adult hinds	Elite hinds (all ages)	Yearling hinds (first calvers)	Weaner stags	Weaner hinds
Apr	Mating activity (rut or roar)		Last of up to weight stags to slaughter	In mating groups. Majority weaned		Artificial insemination and embryo transfer programs	Mating programme using spikers or selected single sires	Pre-rut weaned. First live sales	
May	Stags removed from mobs	On farm, separated from other stock						Weaner sales to finishers	
Jun	On farm wintering				Weaning. Cull hinds to works	Elite stud stock female sales		Weaner sales to finishers. Post rut weaning	
Jul				Non pregnant hinds sent to slaughter				Last weaner sales	
Aug		Cull stock sent for slaughter	Rising two-year-olds sent to slaughter				Non-pregnant hinds sent to slaughter		
Sep	Velvet commences growing								
Oct	Velvet growth & harvest		Velvet growth		Cull at peak prices			Sent for slaughter, chilled venison	
Nov		Cull stock sent for slaughter	Velvet harvest	Calving & lactating		Calving & lactating			
Dec			Velvet harvest and cull					Sent for slaughter, chilled/frozen venison	
Jan									
Feb	Breeding duties			Lactating	Aged dry or wet dry (lost fawns) culled	Lactating		Sent for slaughter, frozen venison	
Mar				Early weaning		Early weaning			Replacements to mating programme

3.3. Main Features Specific to Southland

Deer farming in Southland has particular features that distinguish it from how it occurs in other regions. Southland's winters create challenges for managing environmental effects over longer periods than the rest of the country, but the pasture production cycle matches hind demand during peak lactation. The seasonal day lengths (photoperiod) are well suited to breeding patterns in deer, and both red deer and wapiti are often referred to as 'short-day breeders' (where decreasing day length triggers hinds to become fertile in autumn).

Deer farming is practiced in all land use capability classes (refer to Part A: Section 2.3) although increasingly breeding and velvet production is concentrating in the hill and high country because of competition for flat, productive land. The headwaters and upper reaches of the main river catchments are home to extensive deer breeding operations as part of extensive mixed livestock holdings.

Using Environment Southland's Land Use Map (2015), there are an estimated 210 deer properties in Southland (a farm business may consist of more than one property). The vast majority of these properties are less than 500 hectares, and almost half are less than 80 hectares. A handful of deer properties are extremely large, with the largest in the region being almost 7,000 hectares. Figure B18 shows the number of deer properties by size (total hectares) (the largest property is excluded because it skews the "farm area" scale): 100 farms are less than 80 hectares, just over 100 farms are between 80 and 500 hectares, eight farms are more than 500 hectares.

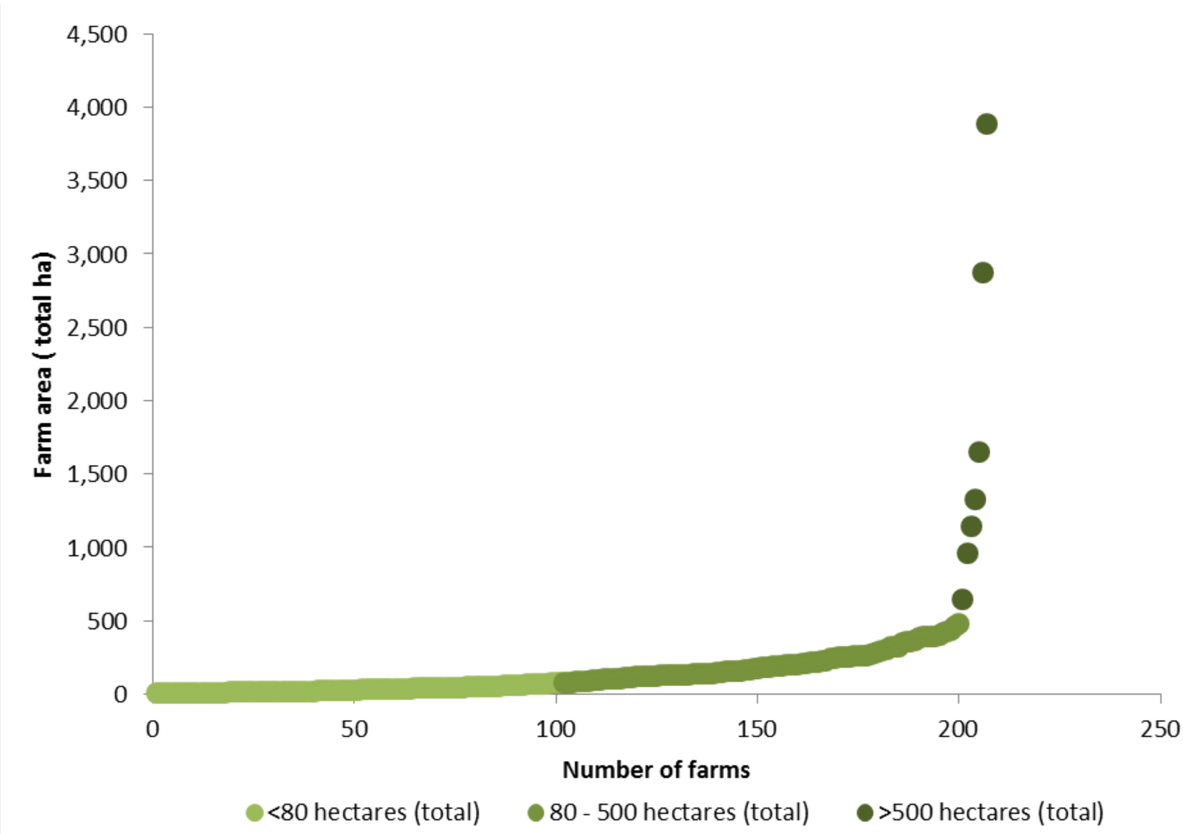

Figure B18: Deer farm sizes in Southland 2015
Source: Southland Land Use Map, April 2015

Winter is a challenging time with conditions being wetter and cooler than the rest of the country, and lasting longer (100-130 days of tough climate conditions are reasonably common). Deer are wintered on brassica crops (swedes or kale), and increasingly fodder beet, generally by break or block feeding. The use of support blocks is reasonably rare in deer farming, with the exception of Landcorp Farming in the Te Anau Basin. Most deer farms are self-contained units, although there may be some owners that have more than one property. Modern deer farms are generally situated where the landscape provides a mix of flats and hill country, and farm management classes (e.g. breeding and finishing) can be achieved on the one property.

Red deer farmers in Southland use dual purpose stag sires for capital (breeding) stock hinds to produce offspring with good antler and growth end points. The region's deer stud breeders also supply favourable deer genetics, particularly in velvet antler, trophy antler and high quality capital stock hinds.

In addition to red deer, Southland is the main region in New Zealand for wapiti farming and has a strong base of wapiti genetics. These multi-purpose large deer interbreed with European red deer, producing fast growing crossbred venison progeny (offspring) that are slaughtered at 9-12 months of age for the lucrative European chilled venison market, fetching the same venison prices as red deer. In comparison to red deer, wapiti are bigger and grow faster, but are less disease resistant. Wapiti are suited to gentler land use capability classes, and red deer perform better in hill country. Southland leads the country in meeting the strong demand for wapiti terminal sires and well-bred wapiti males are also used for a niche velvet antler market.

3.4. Importance of the Deer Industry in Southland

While deer farming is a smaller pastoral industry, it provides an additional source of revenue for farmers and the region, while diversifying the agricultural sector. Southland's farmed deer herd is estimated to sit at around 200,000 head[44], which is roughly 23 percent of the national deer herd (second only to Canterbury with 28%). The region accounts for about 22 percent of New Zealand's venison production, 35% of the venison processing, and 20 percent of velvet antler production. The deer industry's presence in Southland is disproportionately larger than in most other regions, and reflects a number of favourable features for deer farming in Southland (some of which are described above, and others are listed below).

The deer farming livestock system covers most of the mid to upper catchment land use capability classes and uses in Southland. Once widespread, specialist venison finishing farms are now rare; as deer farming's relative profitability to other land uses has diminished on the gentler and more productive land. Competition for land from dairy grazing, some milking platform conversions, and high performance sheep breeding and finishing, have out-performed deer breeding and finishing on these land-classes. The decline of the once thriving Lorneville weaner deer sales market is a symptom of the reduction in specialist venison finishing farms. Finishing is now occurs on the breeding farm.

[44] StatsNZ – Livestock Numbers by Regional Council

As at the end of September 2016, the deer industry generated $246 million revenue nationally[45]. Around 67 percent of this revenue was earned from venison, 17 percent from velvet, and 16 percent from co-products and hides / leather. For Southland, export based revenue is estimated at $65-$70 million for venison and velvet antler, with an additional $12-$15 million in livestock sales for both store stock (deer sold to another farm for finishing) and the stud deer industry.

Although regional figures are not available, Southland's share of revenue is likely to be greater than its 23 percent share of the national herd. With two specialist venison processing facilities and one multi-species processing facility[46], more venison is processed in the region than elsewhere (Lindsay Fung, pers. comm., 2016). As these operations process deer from outside of the region, Southland has proportionally more downstream employment and added value compared with other regions in New Zealand.

The presence of Landcorp Farming Ltd. and other large corporate farmers in the region means Southland also recruits, trains and employs the bulk of the country's deer farm staff and managers. Silver Fern Farms and Alliance Group both employ a large number of venison slaughter plant staff (estimated at about 100 jobs over the peak time) skilled in processing both farmed and wild, high quality, high specification export venison[47].

The deer industry's founders have strong Southland connections and the region makes a large contribution to the national deer industry through leadership and development via both the New Zealand Deer Farmers Association and Deer Industry New Zealand. Two examples are Southland deer farmers' proactive response to the bovine tuberculosis (Tb) issue, which was a particular challenge for the emerging industry, and their active involvement with the AgResearch Invermay Deer Research Centre, and the University of Otago Disease Research Laboratory.

Southland also leads the country in deer sector servicing, through livestock company representation and large, specialised veterinarian practices. A deer specialist veterinary network is based around the original practitioner in Vet South. The network is recognised internationally for their skills and services in deer embryo transfer and artificial insemination, as well as providing veterinary supervision of the velvet antler removal programmes. More generally, the region is a major contributor to the national high quality deer genetics pool and the January sales period attracts buyers from throughout New Zealand for elite young sires and capital stock breeding hinds.

Southland is also home to the largest deer specialist transport companies and is the national hub for wild venison recovery via helicopters. There are several major trophy park operations and other links to international hunting clientele who also engage in adventure tourism, fishing and specialised tourism interests.

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[45] This figure includes the processing of venison and some processing of velvet (but most is exported as frozen raw product).
[46] In New Zealand there are a total of eight specialist venison processing facilities and four multi-species processing facilities approved to process venison.
[47] Although total national kill figures are available, kill figures by plant or region are not because of commercial sensitivities.

3.5. Farm Ownership Types

The deer industry, now established for over 40 years, is well advanced into its succession phase. The next generation of deer farmers is assuming farm ownership, and continuing well-established deer farming enterprises.

Family owned and operated farms remain the dominant business ownership model in Southland. Since the 1980s there has been a trend throughout New Zealand of exiting drystock enterprises, and in particular deer farming, and turning to other pastoral land uses. While this trend has also been a recent feature in Southland, the industry is more entrenched in this region than elsewhere.

Southland has more specialist deer farms (operations where at least 80% of income is derived from deer activity) than other parts of the country, although larger holdings are most likely to be mixed livestock operations. Corporate farming is typical on larger holdings, as is seen with Landcorp's interests in Te Anau. A number of large farms are held within families, but have corporate structures, and are run by advisory boards with farm managers and staff.

The deer industry appears to be in a stabilising period as farms retain hinds for breeding. In the near future it is expected that the regional herd will increase with a change back to increased velvet antler production and a reversal of five years of decline in herd size.

Image B5: Weaners in the Autumn, Catlins
Source: Southland Deer Farmers Association

3.6. Integration of Other Farming Systems

Modern deer farming is a drystock enterprise that can be integrated into sheep and/or cattle over a variety of land use capability classes. While farming different types of livestock on the same property is more challenging, the balance of differing seasonality and feeding, and behavioural demands can maximise outputs from good quality pasture management, and is better achieved using more than one stock class.

The widespread use of sheep, and/or cattle and cropping, or combinations of all of these activities introduces more layers of complexity beyond the three deer production systems (venison, velvet, and stud). As a result, it is difficult to characterise a 'typical' deer farm and the variability was problematic for the modelling of the deer case study farms in **Part C**.

For deer farms that specialise predominantly in deer (i.e. have limited other farming systems), maximising pasture quality and meeting seasonal variations can be achieved by using larger mobs of velvet antler stags as 'cattle by proxy' to clear and control poorer pasture.

Forage crops grown as a supplement for late summer lactation, or as a full or partial winter ration, are suitable for the three major livestock classes (deer, sheep, and beef). These crops may need slightly different feeding management systems than pasture, but they have proven effective in Southland. However, winter feeding systems based on crops have important environmental management issues for heavier stock such as some deer (and cattle) on poorly drained soils.

3.7. Processing and Markets

The NZ deer industry exports 95 percent of its venison, velvet antler, and co-products including: skins and leather, edible offal and the tails, pizzles and tendons favoured in traditional oriental medicine. Venison is mainly exported to Europe and the USA, while velvet is mainly exported to Asia, with Korea and China dominating the market. While the export focus gives deer farmers an economic return under current prices, there is little evidence to date to suggest that current export customers and end consumers will pay additional premiums for sustainably produced products. This constraint requires deer farmers to undertake mitigations outlined in **Part C** 'at cost' – in other words, the cost is borne by the farmer without it generating additional revenue.

The deer industry is engaged in a new market development initiative, supported by all five venison processing companies. It is now combined with an on farm productivity improvement programme *Passion2Profit*. This productivity push is similar to improvements in the sheep and beef industry in better feed, animal genetics for growth, improved animal health, better birth rates and survival to slaughter. With development of new high priced markets, the push seeks to improve on-farm performance and to continue to diversify high value markets. The seven year $16 million investment is underwritten by a Primary Growth Partnership bid with the Ministry for Primary Industries. Conservative estimates suggest that an additional $3.70 per kilogram of venison is available for capture from productivity growth, and premium returns from traditional and new markets.

There is a small high-end demand for chilled venison in the export retail and restaurant trade in traditional European markets, but the industry's future focus is to extend its market reach into new venison markets (USA, north-western Europe and Chinese markets). The bulk of venison is still exported as frozen product, but increasingly markets are demanding a high-end chilled product range produced from August to November. Production in later months of the season is frozen to meet the existing northern hemisphere venison market demand in the following season.

3.8. Future Outlook

Deer farming has many opportunities for the future. They range from the development of export markets for velvet and free trade agreements with South Korea and China to the reversion from deer-fenced dairy support and dairy winter grazing back to deer weaner finishing, and/or breeding and finishing. Many Southland farms have existing deer infrastructure and lower nitrogen loss from deer farming may lead to land use change back to deer in some areas.

The deer industry's strength lies in successful farm succession, new skills and interest from 'Next Generation' farmers, and skilled and trained staff. The major venison processors, Alliance Group Ltd. and Silver Fern Farms, have consolidated their own processing capacities and made a commitment to the industry, particularly through their involvement in the Primary Growth Partnership *Passion to Profit* programme for the production and marketing of venison. The programme's is shown through on-farm initiatives, such as "Advance Parties", which are well-supported groups of motivated deer farmers who find innovative methods or technologies for increased profit and inspire change.

As well as continuing to supply of established markets for velvet antler, the industry anticipates controlled, steady increase in production for new products in the rapidly expanding healthy food market, in both current and new export markets. Further expansion of the industry will add more critical mass and output from the safer summer climate and pasture/crop production potential of Southland and Otago (with less effects from El Nino on breeding hinds and lactation demands).

Image B6: Mature velvet stags
Source: Southland Deer Farmers Association

Indications for the 2016-17 season suggest that venison price expectations will be similar to the previous season, with slaughter numbers remaining the same or potentially reduced by 5-8 percent, because of a slowing in capital stock hind slaughter numbers and some stag retention for velvet production. The velvet antler market is predicted to be stable as markets open up in China and new opportunities in Korea continue to seek velvet antler for the health food market. Preferred product supply is supported by Quality Assurance of food safety, a strong provenance, country of origin verification and a known high animal health status.

The challenge in Southland is competition with other agricultural industries for the gentler, highly productive land (i.e. LUC Classes 1 to 3), which has seen a decline in large venison finishing properties.

3.9. Environmental Issues Linked to Water Quality

Environmental risks on deer farms are different from those faced by dairy, sheep and cattle farmers. Deer behave differently, and are strongly social but competitive in their natural behaviour. Deer behaviour can have specific effects on the farm environment, including to soil and water, the risk of indigenous vegetation damage in the hill and high country, or damage created through overstocking (even on mixed livestock farms). While these behaviours are well understood by deer farmers, on-farm management for these behaviours is not captured well in nutrient management models, such as OVERSEER. The results presented for the case study deer farms in **Part C** of this report need to be viewed with this important limitation in mind.

The key to avoiding environmental damage is in understanding deer behaviour – what activities occur, where, when and why. The social conditions on-farm can differ markedly from the wild, which can conflict with management needs at times, particularly during mating, calving and weaning. Thoughtful management, combining good management practices, genetic selection for good temperament, and environmental knowledge, reduces unwanted deer behaviours and controls environmental risks. When such a management approach occurs it leads to positive outcomes for deer, farmers and natural resources.

The major environmental issue identified by farmers, and confirmed by research (McDowell & Stevens, 2008), is soil erosion along fence lines. This issue is caused by deer walking up and down fence lines in response to behavioural stress (e.g. weaning, or changing mob age and social structures) or disturbance. This behaviour is known in the context of this research as ‘fence pacing’. In combination with adverse weather, it can quickly become a management issue on parts of a farm, with increased soil erosion (and phosphorus loss attached to the sediment), pasture damage, and declining water quality.

Natural deer behaviour includes playing on banks and loose soil, wallowing and camping in areas that can become bare, and they can pug soils in wet weather. On any property, large numbers of young deer indulge in natural play, sparring and greater behavioural competitive activity. When this natural play occurs on erodible hillocks, bare ground or damp/wet areas, it can then lead to unintended erosion or pasture soil damage if not actively managed.

Some deer varieties (English and European reds) readily wallow. If wallows are connected to water bodies they effectively create point source discharges for faecal matter, nitrogen, phosphorus and sediment. Other varieties (wapiti, their crossbred progeny, and Eastern reds) wallow less frequently. Fallow deer do not wallow at all.

The two main nutrients leaving deer farms that create water quality issues are nitrogen and phosphorus; and typically these nutrients take different pathways. Phosphorus tends to escape the farm in runoff events when it is attached to soil particles (such as in dirty water during rainstorms) and washed into water bodies. Nitrogen escapes mainly by passing through the soil and leaching into the water table in the form of nitrate.

In general, nitrogen loss from deer farms occurs at similar rates to sheep and beef farms. Deer excrete small but concentrated urine deposits so, like sheep, they have relatively low nitrogen loss rates. Those deer farms with higher nitrogen losses tend to have specific characteristics, such as irrigation, cropping and / or dairy grazing, the presence of cattle, and certain soil types.

Phosphorus and sediment losses are closely connected and occur mainly through soil erosion, typically on hill country farms. Deer have particular behaviours that increase the risk of soil erosion, and can result in considerable amounts of sediment and phosphorus entering water if not well managed. Deer farms can have 'critical source areas', which are locations or activities prone to a higher rate of phosphorus loss than the rest of the farm. Fence pacing, stock camping, competitive behaviour, and wallowing all create critical source areas for phosphorus loss (Deer Industry New Zealand, n.d.).

In addition to nutrients and sediment, bacteria from deer faecal matter (as indicated by *E. coli*) also affect water quality. The issue will typically result from dung deposited directly into water bodies, and from dung being washed into water bodies – either as run off or from wallows that are connected to water.

More information on environmental issues linked to water quality is available in ***The New Zealand Deer Farmers' Landcare Manual (2012)***.

4. Dairy Farming

Authors: Matthew Newman (Senior Economist), Carla Muller (Agricultural Economist), **DairyNZ**.

Dairy farming is well suited to Southland's flat land, fertile soils and favourable climate for pasture production, particularly from October to April. Dairy farming expanded rapidly since 1990 and now occupies 216,000 hectares (milking platforms) and additional support land, as shown in Figure B19. The majority of this land is Land Use Class 1-4, which is spread across four FMU's. Roughly five percent of the total land used for dairy in Southland is irrigated. Southland is now the third largest dairy region in New Zealand, behind the Waikato and Canterbury.

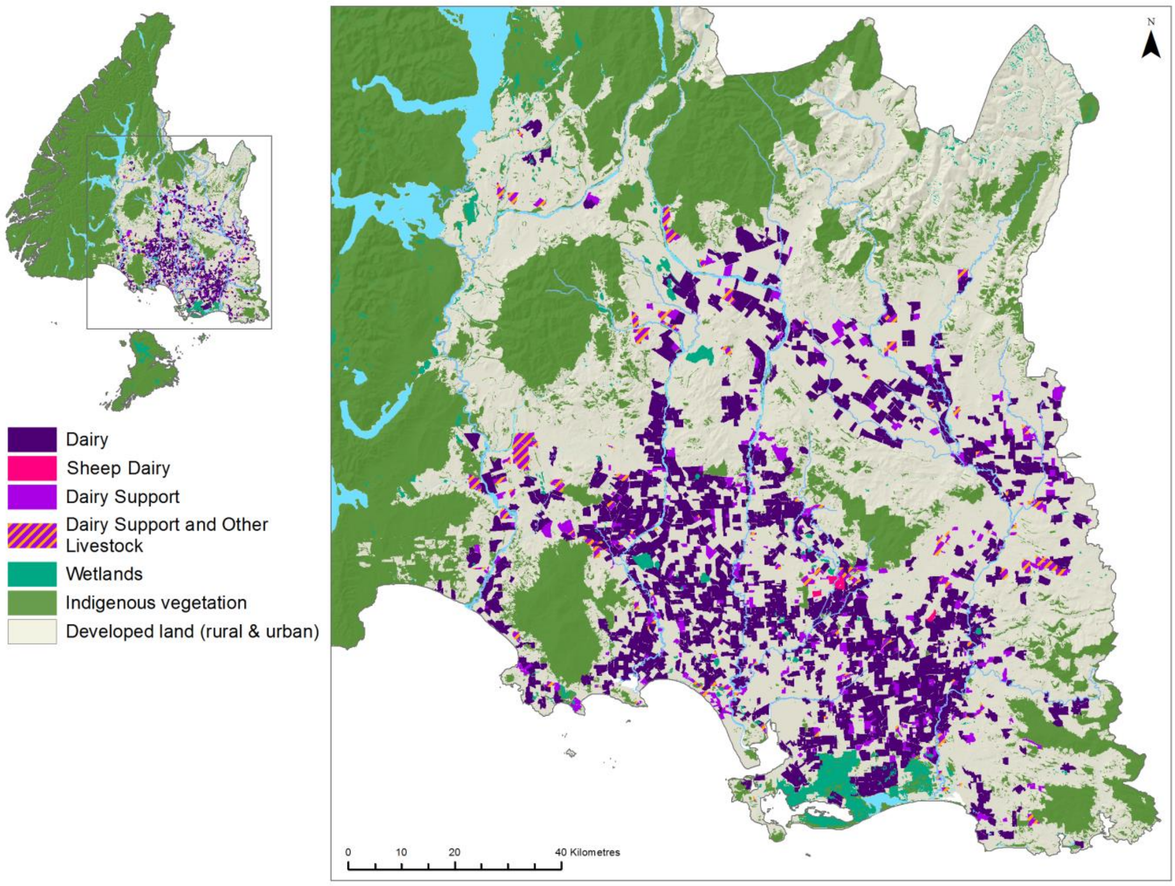

Figure B19: Dairy farming in Southland 2015
Source: Pearson and Couldrey (2016)

4.1. History of Dairy in Southland

The first large dairy herd was established in Southland in 1880 and the dairy industry has maintained a presence since. Dairy farms were originally located on the lower Southland Plains which had heavier soils and regular rainfall making them highly productive. Over the next century dairy farming expanded slowly in line with local demand. It was relatively small compared to other pastoral land uses in Southland and other dairy regions in New Zealand.

In the early 1990s dairying started to grow in Southland. Conversions of land to dairy farms were by local farmers and North Island dairy farmers as well as a group from the Netherlands. High milksolids prices and returns relative to other land uses, in addition to less expensive land than other regions and a favourable climate during summer with frequent rainfall has helped drive this growth.

In the last decade most of the conversions were completed by farmers seeking higher returns from their land or by corporate companies and syndicate/equity partnership investors, who purchased land from retiring sheep farmers (Greenhalgh & Rawlinson, 2013). It included expansion in areas less suitable for dairying, including the upper Aparima, Northern Southland and mid Waiau areas, which often have shallower soils and less rainfall. This expansion into new areas has been helped through technological advancements such as irrigation, fertiliser and artificial drainage.

The growth in dairy farming since the early 1990s has not only increased the sectors contribution to the economy and local communities but contributed to the rejuvenation of Southland.

4.1.1. Southland Dairy Statistics

The New Zealand Dairy Statistics have been compiled in their current form since the 1990-91 season. Over this time, dairying in Southland has changed markedly. Table B9 shows a summary of the size of dairying in Southland every five years since 1994-95.

Table B9: Summary of the size of dairying in Southland

Season	Herds	Effective hectares	Cows	Milksolids (million kg)
1994-95	367	45,231	98,027	26.4
1999-00	520	76,136	196,864	65.3
2004-05	629	111,120	300,047	104.3
2009-10	850	169,749	458,306	172.3
2014-15	971	206,938	573,120	224.8

Source: New Zealand Dairy Statistics

Figure B20 shows the change in total cows, hectares and milksolids production between 1990-91 and 2014-15. It indicates a linear annual growth rate of 11.3 percent (or approximately 23,000 cows per year) for total cows in Southland, 9.9 percent for total effective hectares and 12.8 percent for total milksolids. These statistics make Southland the second fastest dairy growth region, slightly behind Canterbury.

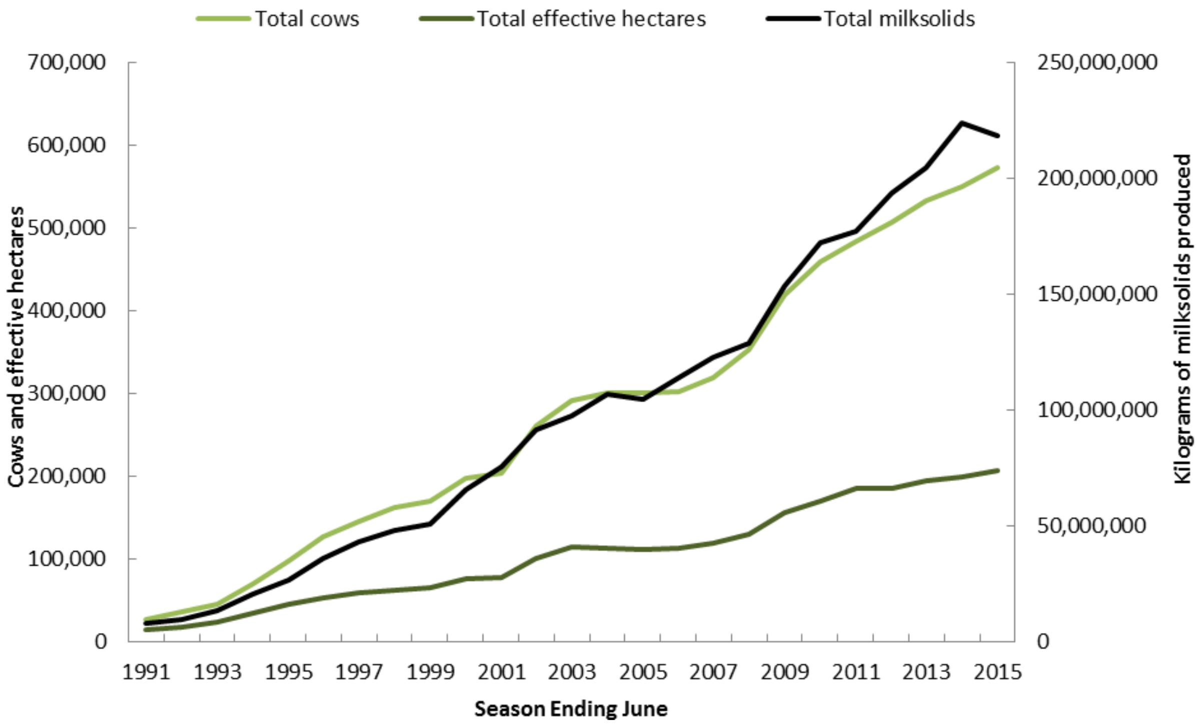

Figure B20: Growth in dairy cows, effective hectares and milksolids in Southland 1990-91 to 2014-15
Source: New Zealand Dairy Statistics

Table B10 shows a summary of the average milk production and size of dairy farms in Southland every five years since 1994-95. In 2014-15 Southland had 971 dairy herds with a total of 573,120 cows and 206,938 effective dairy hectares[48]. This equates to an average herd of 590 cows on 213 effective hectares (or 2.77 cows per hectare). During this period, stocking rates increased 0.6 cows per hectare. However, the majority of cow expansion occurred from growth in hectares and conversions to dairying.

Table B10: Average production and size of dairy herds in Southland

Season	Milksolids per hectare	Milksolids per cow	Stocking rate	Average cows per herd	Average effective hectares per herd
1994-95	583	269	2.2	267	123
1999-00	858	332	2.6	379	146
2004-05	938	347	2.7	477	177
2009-10	1,015	376	2.7	539	200
2014-15	1,055	381	2.8	590	213

Source: New Zealand Dairy Statistics

Figure B21 shows the change in milksolids per hectare, milksolids per cow and cows per effective hectare in Southland between 1990-91 and 2014-15. Milksolids per hectare have increased at a rate of 2.9 percent per year. Just over half of this was due to an increase in milksolids per cow and just under half was due to an annual increase in stocking rate.

[48] New Zealand Dairy Statistics 2014-15

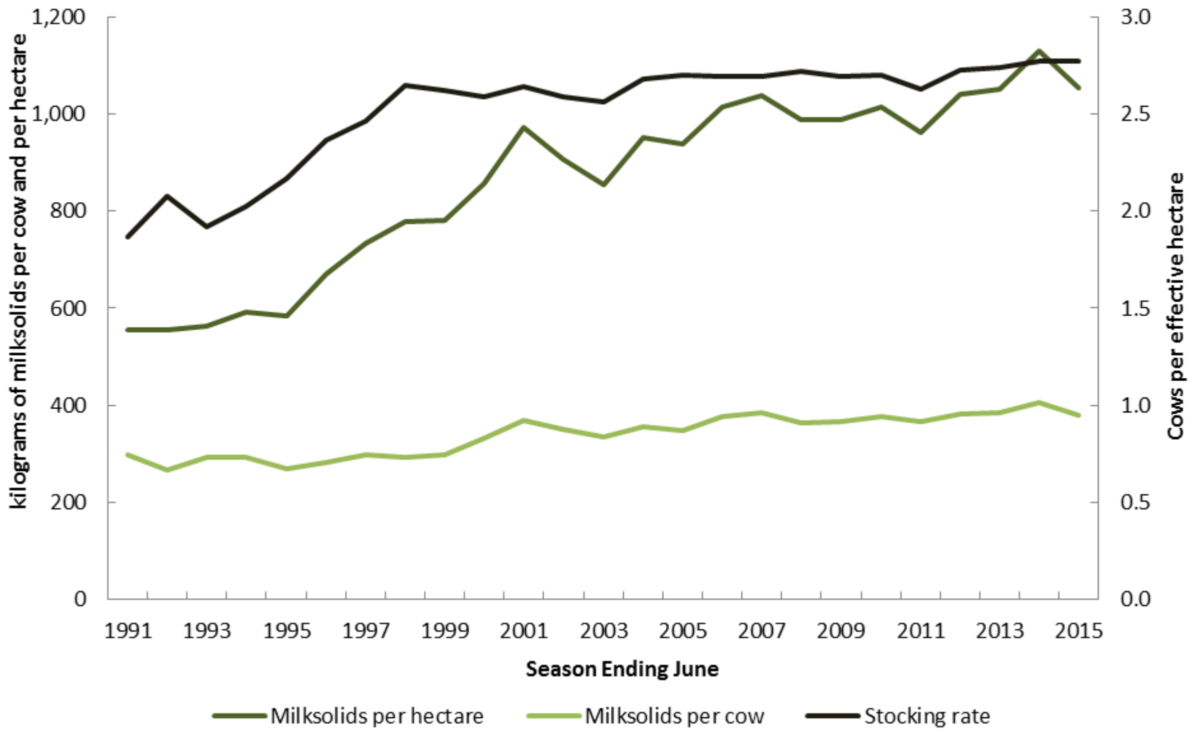

Figure B21: Milksolids per ha, milksolids per cow and stocking rate in Southland 1990-91 to 2014-15
Source: New Zealand Dairy Statistics

Table B11 describes how many hectares are used for dairying land in Southland according to Environment Southland's consents database. These land areas include ineffective areas on a dairy farm and are higher than the 206,938 hectares listed as effective dairy area in the NZ Dairy Statistics (2014-15). The effective hectares in the NZ Dairy Statistics are lower (by 9,723 hectares) than those in Environment Southland's consents database because the NZ Dairy Statistics do not include hectares that are not grazed (ineffective hectares), such as houses, shed, tracks, bush, water bodies and steep areas. These ineffective land areas will have a different nutrient loss than effective areas. The effective hectares in the NZ Dairy Statistics include dairy milking platforms, and exclude any dedicated support blocks.

Table B11: Land area used for milking platform by FMU (ha)

FMU	Hectares in dairy
Waiau	11,961
Aparima	49,052
Ōreti	85,376
Matāura	70,272
Total for Southland	**216,661**

Source: Southland Land Use Map (Pearson and Couldrey, 2016)

Figure B22 indicates the proportion of total dairy land in the Southland region in each FMU.

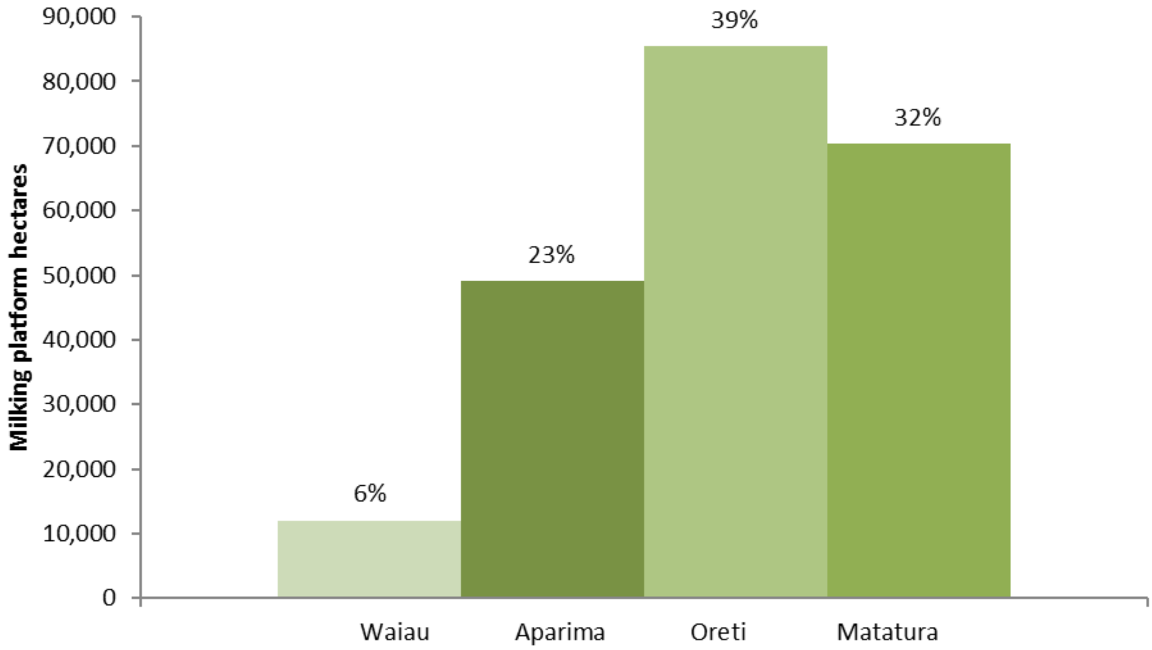

Figure B22: Dairy land (ha) in each FMU
Source: Southland Land Use Map (Pearson and Couldrey, 2016)

4.2. Main Features Specific to Southland

Southland has some differences to other regions, many of which are related to climate. Southland and Otago traditionally has a later median calving date than other regions; in 2014-15 this was the 24th of August[49] compared to the 5th of August in the Waikato.

In 2014-15 Southland had 11.4 percent of the national dairy cows, 8.1 percent of the dairy herds and 11.9 percent of the national dairy land. In the same year Southland produced 218 million kilograms of milksolids, or 381 kilograms of milksolids per cow and 1,055 per effective hectare[50]. In 2014-15, the 971 dairy herds included 64 percent owner operators and 36 percent sharemilkers. This is a similar ownership structure of the national herd, although in terms of sharemilkers there is a higher proportion of variable order[51] sharemilkers (59%) compared to 50:50 sharemilkers (41%) in Southland.

Herds in Southland are typically smaller (590 cows) than those in Canterbury and Otago, however they are larger than the New Zealand average (419). The average stocking rate is slightly lower in Southland (2.77) than the New Zealand average (2.87), but Southland farms are larger (213 eff.ha) than the New Zealand average (146 eff.ha). In 2014-15, half of the herds in Otago and Southland combined were Holstein-Friesian/Jersey crossbreed cows (49.8%) followed by Holstein-Friesian cows

[49] New Zealand Dairy Statistics 2014-15
[50] New Zealand Dairy Statistics 2014-15
[51] A variable order sharemilkers receives a proportion of the milk cheque that is either less than 40% or more than 60%; they pay for a proportion of the operating expenses. They do not own land or cows.

(35.5%), and Jersey cows (5.3%). Compared to the national herd average, there are more Holstein-Friesian/Jersey crossbreed herds and less Jersey herds in both Otago and Southland.

4.2.1. Production System

Dairy farms can be broadly grouped based on the timing, purpose and amount of imported feed used, which is purchased supplements and/or grazing off for dry cows (winter grazing). However, there is no region-wide data collected that captures the system type for all farms. DairyBase[52] captures a sample of farms that have voluntarily entered data and collects a user defined system type and gives the best estimate of the types of farm systems in Southland. In the research in **Part C** of this report, farms are grouped into three categories: low, medium and high input systems.

A definition of the three system types is given below:

Low input system = less than 14 percent of total feed imported and fed to dry cows including dry cows grazing off the milking area.

Medium input system = between 10 and 20 percent of total feed is imported to the milking area to extend lactation (usually autumn feed) and for dry cows.

High input system = more than 20 percent of total feed imported and fed at least at both ends of lactation and for dry cows including dry cows grazing off the milking area.

Feeding policies for young stock are excluded. Figure B23 shows the estimated proportion of farms in each system type in Southland for the seasons 2011-12 to 2013-14.

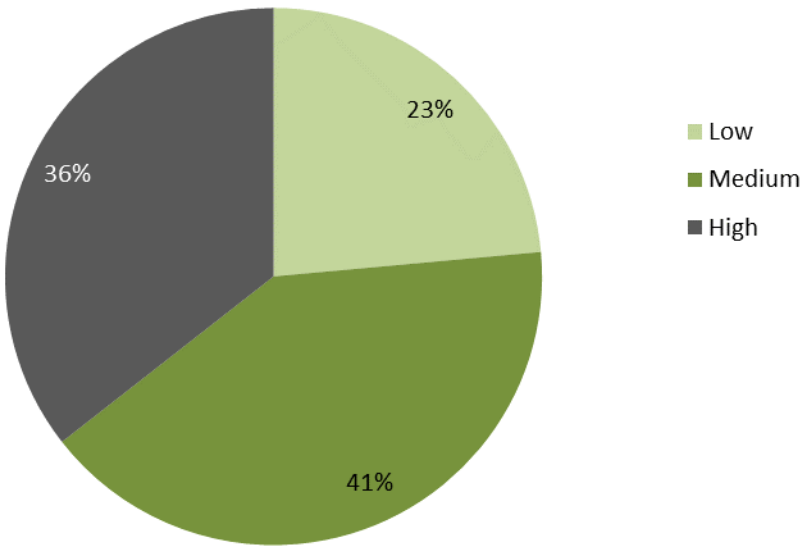

Figure B23: Proportion of farm system type in Southland, average of 2011-12 to 2013-14
Source:DairyNZ Economics Group

[52] DairyBase is the dairy industry's benchmarking tool which records and reports standardised physical and financial dairy farm business information.

4.2.2. Winter Management Practices

Wintering practices are integral to dairy farming in Southland particularly as dairy farms in Southland face a period of little to no pasture production through winter (June and July) when temperatures are too cold (Dalley & Geddes, 2012). Because of this, many dairy farms in Southland rely on crops to feed cows over winter to satisfy their energy requirements. Figure B24 shows the proportions of farms using different wintering systems in South Otago and Southland in 2010; it is based on a sample of 204 farms (which was a quarter of all dairy farms in this area at the time).

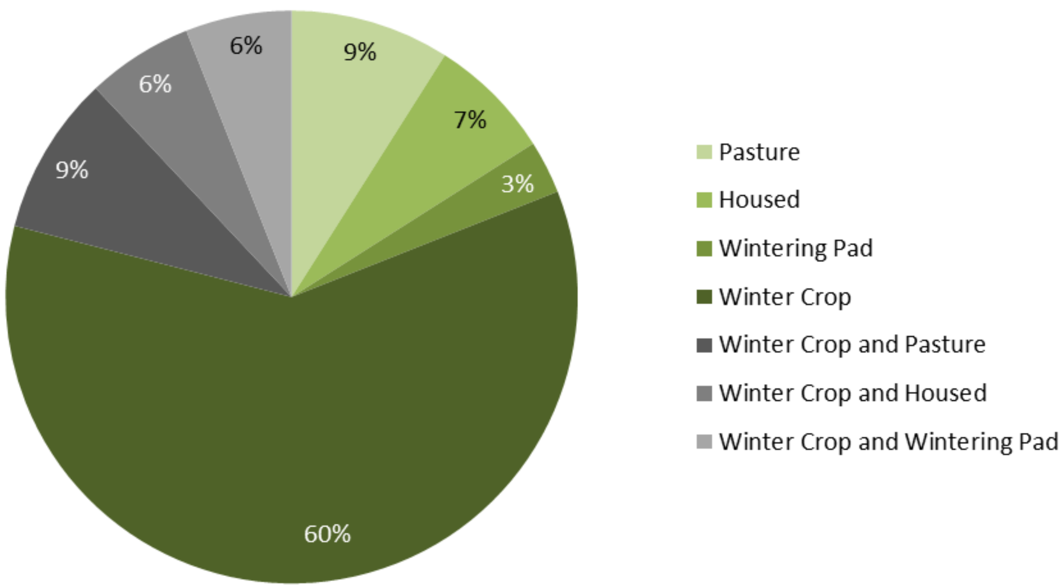

Figure B24: Wintering systems of 204 farms in South Otago and Southland 2010
Source: Tarbotton, Bell, Mitchelmore, & Wilson, 2012

Figure B25 shows the broad wintering practices in South Otago and Southland in 2010 and is based on the same sample of 204 farms. The support blocks can be owned or leased, and the graziers cover a range of farm types, including sheep and beef farmers who provide winter grazing services. This analysis indicates that 16 percent of cows in South Otago and Southland are wintered solely on the milking platform.

Image B7: Dairy cows beside a chou paddock on a dairy farm support block near Ryall Bush
Source: Lloyd McCallum

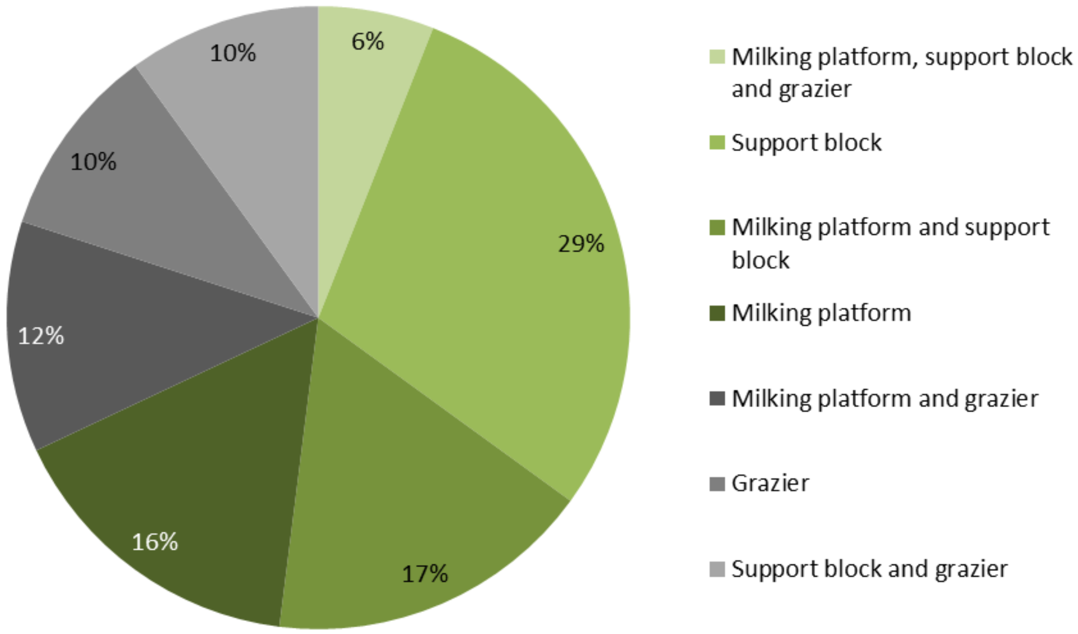

Figure B25: Wintering locations of 204 farms in South Otago and Southland 2010
Source: Tarbotton et.al., 2012

4.3. Importance of the Dairy Industry in Southland

The dairy sector contributed nearly 17 percent ($600 million) to Southland regional GDP in 2012 (Market Economics, 2013). Dairy farming accounts for over nine percent ($373 million in 2012) with the remaining value-added derived from dairy processing. The dairy sector also indirectly contributes to the regional economy through its links with supporting sectors, such as freight transport, storage, packaging and agricultural services. In the first instance farmers spend their incomes on industries that directly support their activities, including purchasing cows, fertiliser and other inputs, upgrading equipment, repaying debt and making land improvements. This means that most of the money earned by farmers is spun out into the communities.

Other land holders in Southland have also benefitted from the expansion of dairying through increased land values. In addition, it has also provided sheep, beef and arable farmers an opportunity to diversify into dairy support, through winter grazing or supplying crops. An average dairy farmer in Otago Southland spent approximately $250 per cow on grazing livestock, off their farm throughout the 2014-15 season. This was approximately 13 percent of total dairy operating expenses.

Dairy farming is a major employer in the region, accounting for approximately seven percent (3,080) of regional employment, while dairy processing employs another 670 people[53]. Southland is one of the fastest growing dairy regions resulting in increased jobs which have flow on effects to supporting service businesses and rural schools. To meet the increased demand for farm workers, migrants (particularly Filipinos) have been recruited to Southland, creating more of a multi-cultural society.

Southland's land mass is approximately 12 percent of New Zealand's land area. The region has 2.1 percent of New Zealand's population, and now has 11.4 percent of New Zealand's total cows milked, which produce 11.5 percent (218 million kilograms milksolids) of the national milk. Southland is the third largest dairy region, behind the Waikato and Canterbury.

4.4. Milk Processing in Southland

The development of milk processors followed soon after the establishment of dairy farming in the region. By the 1920s there were a large number of small dairy co-operatives processing milk for local farmers in communities. From the 1950s improved transportation, processing technologies and energy systems led to the consolidation where co-operatives merged and reduced in number.

Today, Southland's manufacturing base and major enterprises all reside within 70 kilometres of Invercargill. Southland's dairy industry supplies two major processing plants: Fonterra at Edendale and Open Country Dairy at Awarua. The majority of Southland's dairy production is processed into powders (83%) and AMF (Anhydrous Milk Fat) (14%)[54] for export mostly out of Port Chalmers (Dunedin) (approximately 92%)[55], with some leaving from Bluff.

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[53] Statistics NZ's annual Business Demographic Survey 2014. These figures vary from those reported in Section 1.3.1 because of definitional differences between the two sources.
[54] Fonterra, 2016
[55] Statistics NZ

Image B8: Fonterra Plant, Edendale
Source: Simon Moran

The Fonterra Edendale site is the Co-operative's oldest operating manufacturing site and is believed to be the world's largest dairy processing site in terms of volume produced (16 million litres of milk per day at peak). With four dryers, 420,000 tonnes of products are produced, which are then exported to over 70 markets worldwide (Business South, 2016). It has recently undergone expansion with three new plants built creating 40 new jobs to take the total number employed to over 600. The Edendale site plays a big part in the local community, not only through employment but also through sponsorship, environmental initiatives such as Waituna Lagoon planting and support for community activities.

4.5. Future Outlook

Although the expansion of dairy farming is fairly recent, dairying is now established as one of Southland's largest industries. There is opportunity for further conversion of drystock land to dairy farming: DairyNZ estimates that approximately a third of the best land for dairying (LUC Class 1-3) is currently being milked on (164,000 ha). A further 43,000 hectares of land (LUC Class 4-8) is also currently milked on, however DairyNZ does not estimate expansion in these areas.

The rate at which conversion to dairy occurs will largely be dictated by international commodity prices of dairy compared to other industries, land prices relative to other regions, and environmental regulation or compliance rules.

Image B9: Dairy cows on a dairy farm near Ryall Bush
Source: Lloyd McCallum

4.6. Environmental Issues Linked to Water Quality

Dairy farming in Southland affects water quality and soil health in a number of ways: nitrogen (N) losses to water, phosphorus (P) and sediment losses to water, faecal bacteria (*E. coli*) losses to water, and soil structural damage and compaction. These effects can vary considerably from farm to farm, and are largely due to differences in soil type, drainage, rainfall and farm management practices. These environmental issues are relevant to both the milking platforms and dairy support blocks.

The main risk factors for nitrogen losses from dairy farms are excess nitrogen stored in the soil profile and the extensive network of tile drains. The most important determinant is the amount of urinary nitrogen, and large nitrogen losses can occur when urine is deposited on the soil shortly before rainfall events. Other important determinants are excess nutrients applied to pasture and crop, winter grazing management, and management of dairy farm effluent. The pathways for nitrogen losses to water are overland flow, artificial drainage to surface water bodies and deep drainage to groundwater. Mitigations include reducing the accumulation of surplus nitrogen in the soil, particularly during autumn and winter, and avoiding preferential flow of farm dairy effluent through tile drains.

The main risk factors for phosphorous losses from dairy farms are the loss of particulate material from the soil, washing off of phosphorus from recently grazed plants, effluent deposits and the use of fertiliser (including farm dairy effluent). All of these factors, except for fertiliser use, are influenced by stock grazing (whether it is the ripping of pasture plants or treading), which influences soil erosion and compaction, and surface water run-off. A large proportion of phosphorus losses is from a farm’s critical source areas.

The flow of water overland is the major flowpath for much of the phosphorus from dairy farms. Where artificial sub-surface drainage exists, phosphorus losses can be the same as losses from overland flow, due to the entrainment of particulate and dissolved phosphorus as water moves through the macropores and fissures to tile or pipe drains. Examples of mitigations are avoiding preferential flow of farm dairy effluent through tile drains, reducing the use of phosphorus fertiliser where Olsen P values are above agronomic optimum, using low solubility phosphorus fertiliser forms, fertilising outside of risk months (May to September), stock exclusion from water bodies and appropriate riparian filter strips.

Dairy farms on flat land have a lower risk of sediment loss than farms on other slope classes because of the contour of the land. However, sediment can be lost through pasture renewal, cropping, critical source areas and stream bank erosion. As well as sediment losses, many dairy farms are located on heavy poorly drained soils that are vulnerable to treading damage and pugging damage by stock when wet. This damage can cause compaction, which might affect soil drainage, possibly reducing the accessibility of nutrients by plants, which can be costly to rectify. An important mitigation is being strategic about the grazing on susceptible soils during wet conditions, particularly for winter forage crops. Artificial drainage to improve soil drainage on heavy soils can also mitigate the risk of pugging.

Faecal bacteria come from the deposition of effluent on grazed pasture and crop land, and from the application of dairy effluent. The major pathways are surface runoff from grazed pastures, preferential flow through sub surface drainage and direct deposition into water bodies. Nearly all dairy farms in Southland have excluded stock from water bodies and the risk of direct effluent deposition is low.

One of the ways dairy farming effects on water quality can be reduced is through management of high risk areas. Management of critical source areas can considerably reduce phosphorous and sediment losses. Winter cropping can be managed through strategic grazing, crop selection and adequate buffers. Stock exclusion from water bodies and riparian buffers also help manage losses of bacteria, sediment and sediment-bound phosphorus, as well as improve ecological health.

Farm dairy effluent is a major risk if not managed well. Farmers are required to have consents to manage effluent and by having sufficient effluent storage and appropriate application practices will reduce this risk.

5. Arable Farming

Authors: Diana Mathers (Research Manager – Farm Systems), **Foundation for Arable Research**; and **Environment Southland** staff.

The location of arable farming is where there is the growing of crops; grains, vegetables, seeds, forages and fodders for human consumption and stock feed. The nature of this type of farming, and the need to rotate crops around a farm, means that in Southland there is usually a mix of crop and livestock enterprises[56]. There are an estimated 23,400 hectares of arable farms In Southland, each with different livestock and crop type rotations. The main cash crops are barley, wheat (feed and milling grades), oats, field peas and oil seed rape. Southland's arable farms are shown in Figure B26.

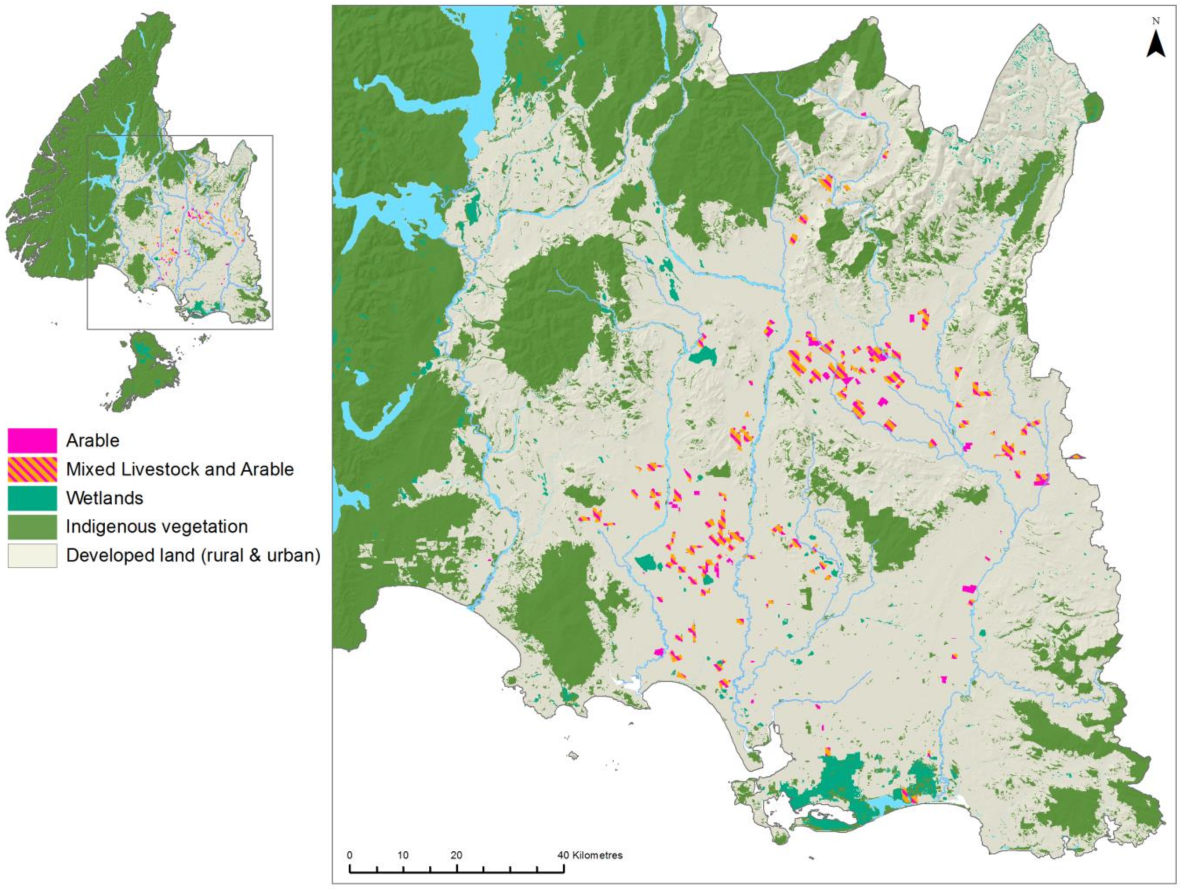

Figure B26: Arable farming in Southland 2015
Source: Pearson and Couldrey (2016)

Arable crops (grains and seeds) are grown on free-draining land, usually silt loams and alluvial soils. While these crops are occasionally grown on slight slopes, the preference is for flat land. Fodder crops, such as brassicas and beets, are key components of many arable farm systems and are grown on both flat and rolling land.

[56] Arable Farms are those farms where the farmer identified themselves as arable within Agribase. Mixed Livestock and Arable Farms are those farms where the farmer identified as a specific livestock category, but have large areas of arable cropland (greater than 20% of their total farm area). In general, arable farming in this report refers to both 'arable' and 'mixed livestock and arable' farms.

Arable crops, particularly forage and fodder crops, do not only occur on arable farms. Many drystock farms have some aspect of arable cropping, specifically winter forage and fodder crops, generally for their own stock. The forage and fodder crops for stock include annual ryegrass, forage oats, forage brassicas (e.g. turnips, swedes, kale), fodder beet, and cereals (e.g. oat and barley) for cereal silage production. Forage and fodder crops are either grazed in situ or sold-on to dairy and drystock farmers. Figure B27 shows the extent of forage crops grown over winter in Southland in 2014. In 2014, an estimated 68,280 hectares in Southland was used for winter forage crop – although just 2,290 hectares of this area was grown on arable farms (Pearson, Couldrey, & Rodway, 2016).

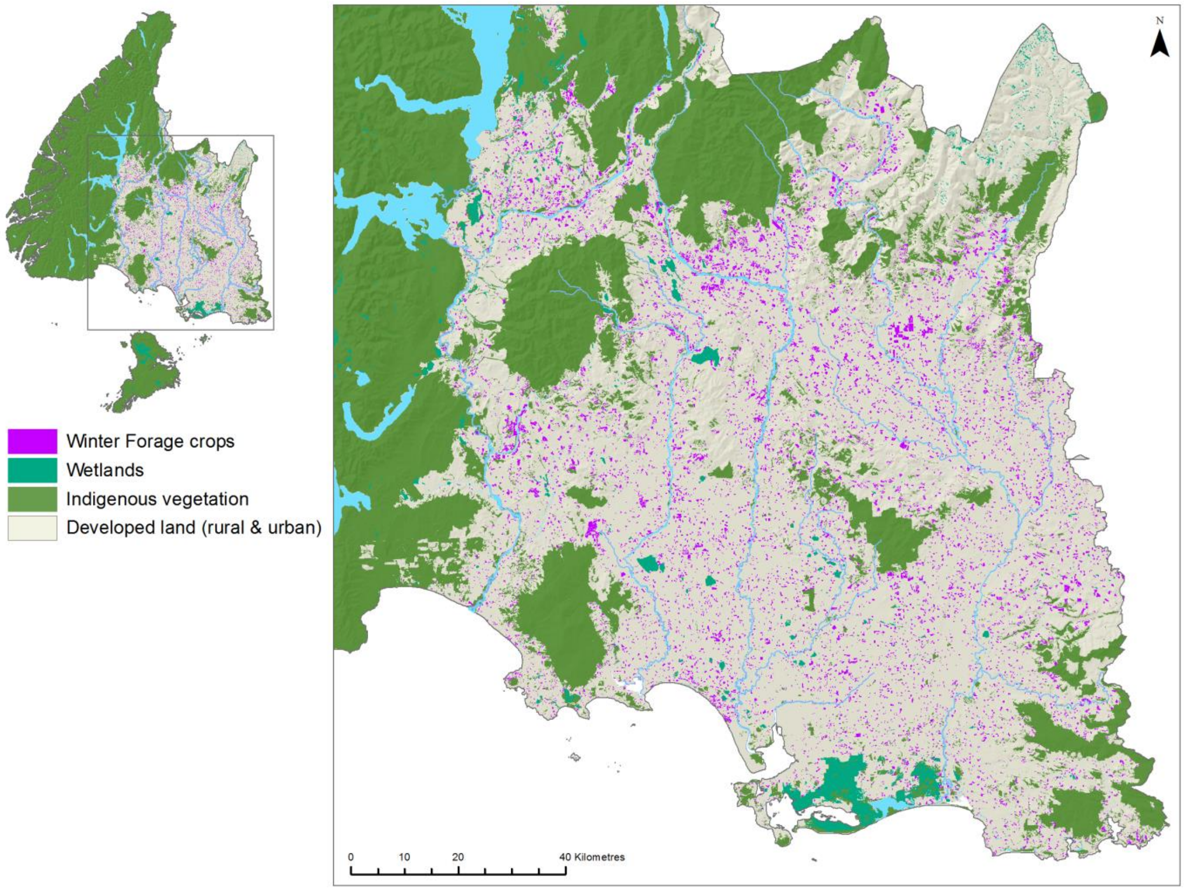

Figure B27: Extent of winter forage crops grown in Southland in 2014
Source: Pearson et al. (2016)

5.1. History of Arable Farming in Southland

Arable farming was established early in Southland's European settlement and the region has a strong tradition of growing wheat, barley and oats. This history reflects the importance of milling wheat and oats as staple foods and barley for brewing, particularly before transport links were developed, and the suitability of the region to these crops. While still important to Southland's economy, oat and wheat production was surpassed by lamb and dairy production by the 1950s (Ashwood, 2011). Yet even in the late 1970s, Southland was still producing the highest yields of wheat and oats in New Zealand (Ashwood, 2011). Ever since flour milling ended in the region in 2006, the growing of milling wheat has declined markedly. Despite this shift, arable farming in Southland covers a wide diversity of crops and grazing systems.

In Southland, arable farming is now strongly integrated with both drystock farming and dairy farming. Arable farms are diverse businesses and it is rare to find one in Southland with no stock in its system. The majority of Southland's arable farms are mixed enterprises, where a rotation of grain and seed crops is included with sheep, beef and/or deer production, and forage crop rotations for stock feed. Arable crops often compete with dairy farming for free-draining flat land and land prices for arable land have increased over recent years.

5.2. Main Features Specific to Southland

In Southland, just under 10,000 hectares of grain and seed crops, and 180,000 hectares of supplementary feed crops were harvested in the year ended 30 June 2012 – or a total of around 190,000 hectares of crops (Statistics New Zealand, 2012). Table B12 gives the areas of grain and seed crops and of supplementary feed crops harvested in Southland in the year to the end of June 2012.

Table B12: Arable crops in Southland (year to end June 2012)

Grain and seed crops	Hectares harvested	Proportion of total
Wheat	2,505	25.5%
Barley	5,700	58.0%
Oats	1,240	12.6%
Field / seed peas	278	2.8%
All other grain and seed crops	105	1.1%
Total	**9,828**	
Supplementary feed crops	**Hectares harvested**	**Proportion of total**
Maize silage	264	0.1%
Pasture/Lucerne (hay silage and baleage)	115,168	64.0%
Cereal silage or cereal baleage	5,571	3.1%
Other crops silage	2,960	1.6%
Lucerne	1,445	0.8%
Maize green feed	208	0.1%
Forage brassicas	52,946	29.4%
Other supplementary feed crops	1,335	0.7%
Total	**179,897**	

Source: StatsNZ – 2012 Agricultural Census

Arable farms are dynamic - it is an essential characteristic of an arable farm that they change. Arable farmers are opportunistic and have innovative business systems: they make business decisions about the proportion and mix of crops and stock on their farm each year. Market forces drive these decisions and arable farmers focus on gross margins in their decision-making. Their economic and environmental performance is related to the integration of the different enterprises on a farm. The majority of arable farms in Southland are owned and operated as family businesses, often with the land being passed down through several generations. Most farmers manage their own ground work and harvesting operations but may use contractors at peak periods. The larger farms often have farm managers.

Almost all barley and wheat is now grown for stock feed, and most of it is used in the dairy industry. Oats are grown for grain and cereal silage, and are used as a break crop for wheat, and a 'weed cleaning' crop on sheep and beef farms before land is returned to permanent pasture. Most oats are spring sown after brassica crops but around five percent of oats is autumn sown.

Image B10: Arable Farming in Northern Southland, near Balfour
Source: Matt Couldrey

Other crops grown in smaller quantities are small seed crops, including herbage, vegetable seeds such as peas, and oil seed rape. These crops are limited because of the lack of infrastructure for cleaning seed crops in Southland. Cereal silages and fodder (or forage) crops, such as kale, swedes and fodder beet, are grown for animal production systems, either being traded off the farm or feed on-farm to farm stock and for contracted grazing.

It is common for water, rather than nutrients, to be the input in production systems that constrains crop yield and this has a cost for both the environment and the profitability of the system. The ability to irrigate crops efficiently is often fundamental to managing nutrients and low nutrient losses to groundwater. There is some irrigation of crops in Southland, particularly in Northern Southland, and in 2017 there were 22 permits for consumptive water takes relating to crop irrigation.

Dairy prices and grain prices are closely linked and, with the expansion of the dairy industry in Southland, intensive winter dairy grazing has become a common component of arable farms. Arable farmers provide dairy support for Southland's dairy industry by grazing calves and heifers, and in the wintering of in-calf cows on forage crops. However, some farmers are shifting away from dairy grazing because of the environmental impacts which are a cost to their business. Dairy expansion has also put pressure on the land available for cropping. The short-term financial returns for winter dairy grazing are good, sufficient enough for arable farmers to 'give it a go'. The 'down-side' of providing dairy support is that it can have on-going, negative impacts on the profitability of the arable farm over the following years.

5.3. Importance of Arable Industry in Southland

Arable farming is covered by three categories in Statistics New Zealand's Business Frame, rather than a single category, reflecting its strong connections with other agricultural industries but making it challenging to get industry specific data. In Southland there were 108 'jobs' in 2014 in Grain-Sheep and Grain-Beef Cattle Farming, 38 in Other Grain Growing and 188 in Other Crop Growing (which includes fodder crops) (Market Economics, 2013).

In 1981, Southland contributed 23 percent of New Zealand's total wheat production but within 20 years this share had declined sharply in the face of cheaper imported wheat from Australia following market deregulation in the 1980s. Flour milling ended in Southland in 2006.

Between 2007 and 2015 the region's wheat production increased 136 percent, or from under four percent to almost ten percent of New Zealand's total wheat production. The area of wheat land harvested increased from 1,400 hectares to over 3,000 hectares with a shift from milling wheat to feed wheat. The average yield for wheat was 9.17 tonnes per hectare between 2012 and 2015.

During the same time period (2007 to 2015), Southland's barley production increased 108 percent, or from just over six percent to almost eleven percent of New Zealand's total barley production. The area of barley land harvested increased from 3,100 hectares to 6,400 hectares. The average yield for barley was 6.82 tonnes per hectare between 2012 and 2015.

In 2015, Southland was the second largest region in New Zealand for wheat and barley production (tonnes harvested) after Canterbury. It was also the second largest region for oat production (tonnes harvested) in 2012 (the latest year figures are available). Figure B28 shows arable farming in Southland is expanding, with sizeable increases in the tonnage of barley and wheat harvested. These trends are likely to be related to the demand for grain from the dairy industry.

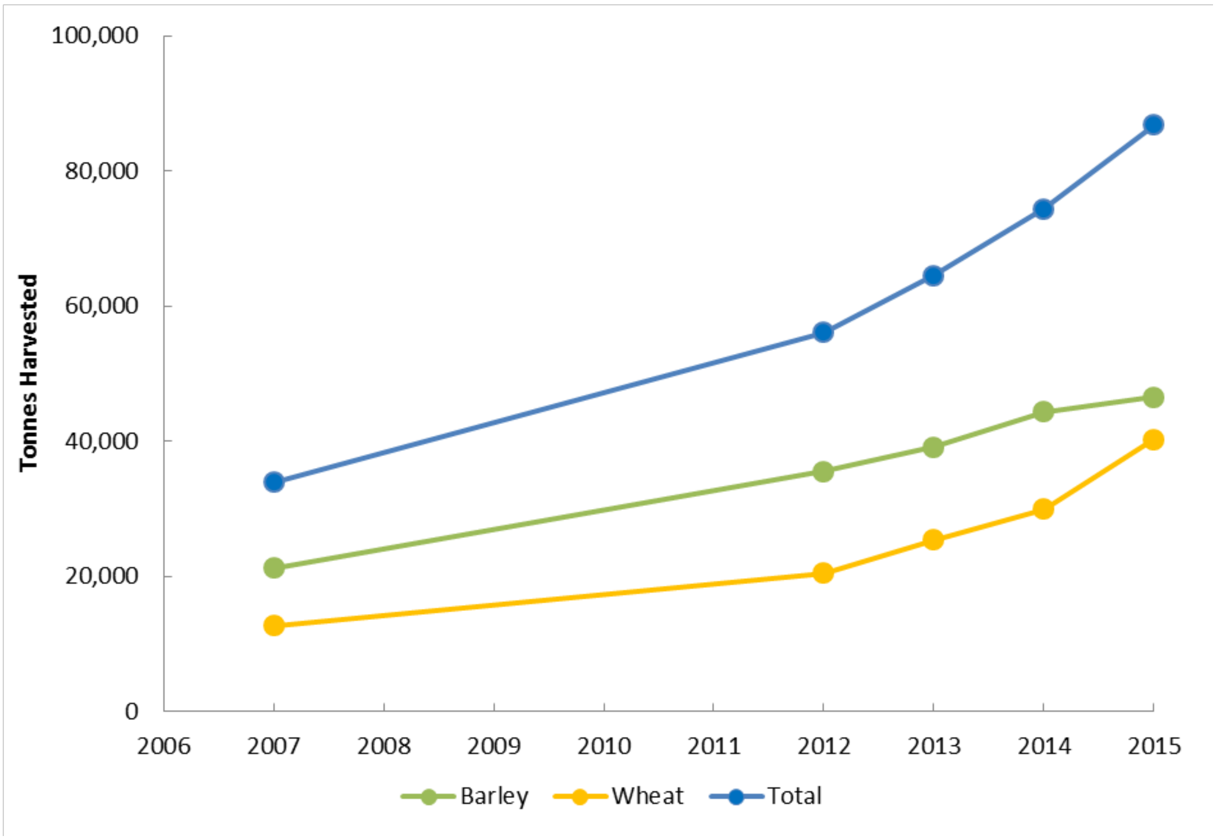

Figure B28: Quantity of wheat and barley harvested in Southland (year ended June) 2007-2015
Source: Environment Southland

5.4. Processing

Southland's flour mills were established during early European settlement and, at their peak in the 1880s, there were 12 flourmills operating in Southland, such as the Winton Mill and Reid's Mill at Gummies Bush. Flour milling was one of the region's most enduring industries and it played a major role in its economic development (Ashwood, 2011). For example, owners of the Matāura paper mill built a flour mill for the community in response to concerns about their proposal to secure sole rights to all of the Matāura Fall's potential for hydropower. The flour mill was demolished in 1892 to make room for a freezing works (Muir, D. C. W. (ed), 1991).

For over a century, Southland was one of the most important flour producing regions within New Zealand, and this success is linked to the Fleming and Company Flourmill in Invercargill (built in 1876). Over time Fleming and Company acquired all other mills around Southland and the company became a household name in New Zealand. The Invercargill mill was closed in 2006 (Ashwood, 2011). With the closure of the Invercargill mill, crops of milling wheat have to transported and processed in Canterbury. The limited of processing infrastructure (e.g. flour mills, dryers, seed cleaning) is a major constraint on the arable industry all over New Zealand.

Alongside wheat, oat production also has a strong tradition in Southland, particularly around Gore. Fleming's Creamoata factory in Gore was the home of the oatmeal porridge (and the iconic 'Sergeant Dan') that was the staple breakfast for New Zealand children during the 20th century. The fcatory was built in 1919 and eventually closed in 2001 when the overseas owners shifted the operation to Australia (Zydenbos, 2008). Oats are now mainly grown in Southland for processing into breakfast cereal at the Harraways plant in Dunedin, as well as for stock food.

Image B11: Fleming's Creamoata Factory, Gore
Source: Simon Moran

5.5. Future Outlook

Southland's arable industry is closely integrated with both the dairy and the sheep and beef industries, and so future challenges and opportunities for those industries will flow-on through to arable. A good example of this integration between industries is how dairy prices can impact on forage and feed grain prices.

Challenges for arable farming in Southland include a lack of local infrastructure to process arable crops, particularly flour mills and seed cleaning equipment. The successful processing of crops requires an efficient pathway from the farm to the customer, and local processing minimises the logistical costs. The current dependence on commodity markets, and integration and dependence on other industries creates price instability. Another challenge is increasing environmental constraints, including managing nutrients in integrated pastoral and cropping systems, and maintaining soil quality for ongoing productivity. A related issue is increasing compliance costs and constraints on the farm business connected with meeting environmental policy. Maintaining profitability for crop products and a range of opportunities help farmers have flexibility in their rotations.

Opportunities for arable farming include ongoing integration with the dairy sector to grow forage crops, cereal silages and grains for cut and carry systems and in-situ grazing for dairy heifers and wintering off for dairy cows; and grain and cereal silage production for intensive lamb and cattle finishing systems. As the maize industry begins to offer hybrids better suited for cooler climates, the region will see an increase in maize silage production.

Another opportunity is the manufacture of oat milk as a substitute for cow's milk. Feasibility and market opportunity studies for increased oat production and oat milk manufacture from a Southland base have been completed. The potential market is in Asia, and products will include both milk powder and whole oat milk product.

Arable farming's best opportunity for profitability is more diverse market opportunities, including demand for crops with added value (e.g. high value seed foods and food ingredients). An increase in seed production is constrained by the risky nature of the weather during the harvest season. However, there may be small pockets of land within the region that are high suitable for seeds.

5.6. Environmental Issues Linked to Water Quality

In Southland, the environmental risks of mixed arable farm systems come from the joint management of the crops and the stock. Water quality may decline when nitrogenous fertilisers, such as urea and sulphate of ammonia, are applied in excess of the crop and pasture demand; soil nitrogen is leached during drainage events via tile and mole drains, and soil profiles. It may also decline when long term pasture is cultivated for cropping as part of pasture renewal management and soil mineralisation releases more nitrogen than the crop can use.

Cultivation practices lead to sediment losses during rainfall and the overland flow of water. The movement of sediment is closely linked to phosphorus losses, especially when soil phosphorus levels are high. Reduced tillage practices such as strip tillage and direct drilling are effective in limiting the level of soil disturbance and sediment loss from exposed ground during wet periods.

Soil structure is damaged, sediment is lost and nitrogen is leached following intensive winter dairy grazing of crops. This single component of a mixed arable system has a high environmental risk of long-term soil degradation and nitrogen and sediment losses to water. Farmers report that their biggest concern following winter dairy grazing is the long-term damage on soil structure, which in turn impacts on crop yield and imposes remediation costs. It is crucial for the arable industry that the productivity of the soil is maintained. Degraded soils with compaction and poor soil structure take time to recover, and there is an on-going impact on farm profitability during this period.

No arable crop is markedly better or worse than others in terms of nutrient and sediment losses. Environmental risks from particular crops occur more through poor management practices, either related to crop production or the grazing management of the crop. Some management practices for crops have a direct bearing on nutrient and sediment losses. These practices include managing the amount, timing, placement and formulation of nutrient applications; and understanding the supply of nutrients to the crop from the soil. They also include managing cultivation of crops to protect soil structure; reducing the risk of compaction and the breakdown of soil structure through poor grazing and cultivation; and improved irrigation efficiency from a well maintained system while understanding of the crop's requirement for water (i.e. water is not wasted).

6. Horticulture

Author: Angela Halliday (Manager, Natural Resources and Environment), **Horticulture New Zealand**; Stuart Ford (Director), **Agribusiness Group**; and **Environment Southland** staff.

Horticulture in Southland revolves around the growing of vegetables and tulip bulbs. Vegetable and tulip bulb growing occupies areas that are relatively small compared to other farming systems. The availability of this land is highly competitive, with other industries dominating the use of these productive soils. Horticulture and tulip bulb growers produce high value crops that are generally labour intensive, with planting, harvesting, processing and packing required to get produce to market. In Southland, the growing systems are linked to sheep farming with the crop rotations moving around a number of sheep properties and a few dairy properties (the milking platform only – not support blocks). This production system helps maintain soil structure and integrity (or intactness) and minimises the build-up of pathogens in the soil. Vegetables and flower bulbs are produced for markets within New Zealand and exported internationally.

This section gives an overview of vegetable growing and tulip bulb growing in Southland, particularly the nature of the each industry in Southland, its employment and markets. It then discusses their future outlook and environmental issues related to water quality. As a result of the small size of the industry in Southland, there is only limited information available on horticulture. As well, although tulip bulb growers have formed a loose network they are not represented by an industry group. A brief written survey of vegetable and tulip bulb growers was carried out to fill in some of the knowledge gaps. The four growers who responded to this survey represent a sizeable portion of each industry.

6.1. Vegetables

Commercial horticulture has been established in Southland since at least the early 1900s. The cool soil temperatures create ideal growing temperatures for root vegetables with frosts making vegetables like parsnips sweeter and also help to control diseases. The regular rainfall means that generally little to no irrigation is required (although some may be needed over the summer months).

Southland is the primary base of two major root vegetable growers, Pypers Produce Ltd. and Southern Cross Produce Ltd., who supply much of the South Island with carrots, parsnips and potatoes. These vegetables are grown year round and, at certain times of the year (such as winter); Southland is the only hub supplying some of these products (particularly carrots) to the New Zealand domestic market. The region's vegetable produce is also exported to Australia, Asia, and the Middle East.

Horticulture is a labour intensive industry. The two vegetable growers employ a total of around 70 full-time staff and 40+ seasonal workers (mainly locals) over the peak season, which lasts from early autumn to spring. Unlike the pastoral and arable industries, horticulture is vertically integrated with growers growing, harvesting and processing their own products. The vegetable growers have been growing and marketing produce in Southland for two generations. They are actively involved in local communities, supporting the Salvation Army food kitchen, local rugby clubs (e.g. Wrights Bush), and early childhood education.

The region usually has just over 500 hectares of planted vegetables, mostly carrot, potatoes and parsnips. The proportions of each root vegetable vary from one year to the next depending on market demand and availability of horticultural land. In 2015 around half of the growing area was planted in carrots, almost one third of the area was in potatoes, and one sixth was in parsnips. There was also a small area of beetroot grown for the fresh vegetable market. The growers try to avoid areas where the wintering of dairy cows has occurred because damage to soil structure makes it extremely difficult to develop a fine seed bed.

Image B12: Carrot paddock near Invercargill
Source: Brendan Hamilton

A series of different vegetable crops are grown for roughly three years before the block is returned to pasture for at least six seasons before the rotation is repeated. Vegetables seldom need to be irrigated in Southland although occasionally it is needed during drier months. When irrigation is needed, water is taken from ponds and occasionally recycled from washing processes.

The rotational nature of root vegetables means that vegetable growers only own between 10 and 20 percent of the land for their crops. Most of the growing area for vegetables is on land leased from sheep and beef farms. This land is located around Woodlands and Waimatuku, with a small area of potatoes grown around Edendale. The expansion of dairy farming has reduced land availability, and both growers are increasingly looking to buy land. The high proportion of leased land means that changes to freshwater management (depending on how it is implemented) may impact vegetable growers quite differently to farmers, particularly around the availability of horticultural land.

6.2. Tulip Bulbs

The first commercial tulip bulb grower in Southland was Dutch and established in West Plains, near Invercargill in 1952. Many growers now still have ties to Holland, but most staff were either born in New Zealand or have lived here for a long time. Their focus is on tulip bulb production (and the size of the bulb), although cut flowers are also produced. Other flower bulb crops are grown on a smaller scale, such as irises and crocuses. Southland is the only commercial tulip bulb growing region in New Zealand. Its favourable climate and rich, heavy soils have earned it a reputation for being an ideal place for growing tulip bulbs. The end of the growing season is cool, putting less pressure on the plant, which keeps on growing (Rudd, 2013).

As of mid-2015, there were five main companies growing tulips in Southland. The bulk of the tulip bulbs are exported to the Netherlands, the United States and Canada, and also to Scandinavia, Japan and Russia. The bulbs are exported mainly from Port Chalmers, Dunedin but with a small quantity leaving from Bluff. Port Chalmers is the preferred port because it tends to be a cheaper and quicker option to transport bulbs to Europe. These tulip bulbs are used to fill an ‘out of season’ gap in the Northern Hemisphere production. Bulbs from Holland can flower year round, but for six months of the year these tulips are of lower quality. New Zealand bulbs produce good quality tulips during this time and stand out in flower markets. Other Southern Hemisphere countries, such as Chile and Tasmania, also produce ‘out of season’ tulip bulbs, but they flower best in the Northern Hemisphere in September and October. Southland bulbs flower better there in November and December, when supply is shortest, and demand high for Thanksgiving and Christmas (Rural Delivery, 2015).

Image B13: Tulip bulb growing in Southland
Source: Tim Ellis

Tulip bulb growers in Southland usually employ four to five staff each, and up to a hundred additional seasonal workers (roughly one person per hectare) at peak seasons during planting, harvesting and exporting. Most seasonal workers are New Zealanders, and many are students from Otago University, with their summer break coinciding with the bulb harvesting season. In Southland, tulip bulbs are planted in April and May and flowers bloom (and are removed) a few weeks later in October and November. The bulbs are harvested in January and February before being exported in April and May.

Around 300 hectares of tulip bulbs are grown in Southland annually. Growers lease almost all of this land, competing between themselves, and with other industries, for horticultural soils. After a year in tulip bulb production the land is returned to pasture. The aim is for tulip rotations that are as long as possible to avoid the build-up of pathogens and diseases in the soil. In the past growers have achieved 12 year rotations, but now competition for land means they are restricted to a six to eight year rotation. Occasionally, tulips will follow vegetable because of the increased soil fertility.

Tulip bulb growing areas are mostly located around Edendale (Matāura FMU) and Woodlands (Ōreti FMU), although there is a grower operating as far north as Balfour (Matāura FMU). These areas have soils similar in clay and organic matter to Northern Holland, where most of the bulb crops in the Netherlands are grown. Tulip bulbs have two distinct growing periods: before flowering, and once the flower has been removed. Depending on rainfall, the bulbs can need irrigation during the second growth period as the roots have to stay moist for a bulb to reach the required size for markets. Generally, tulip bulbs are irrigated using big guns from a bore either onsite or nearby.

In 2015 the value of tulip exports was $9.7 million, a decrease from $11.6 million in 2014 (Horticulture New Zealand, 2015). The tulip bulb industry has barriers to new entrants with the capital required to set up and the production knowledge needed. Since most of the growers in New Zealand are linked to major companies in Holland, their experienced staff are often sent over from Holland to give guidance to New Zealand growers.

6.3. Future Outlook

The future outlook for horticulture in Southland has both challenges and opportunities. A challenge for growers is continued access to horticultural soils. Vegetables growers are increasingly choosing to buy land to future-proof their businesses. Even if land is owned, it is still desirable to include sheep in rotations so cultivated land is returned to pasture because it protects the soil's structure and productive capacity over the longer term. Tulip bulb growers prefer to lengthen their rotations if possible, and there is increasing competition for leased land with good quality soil, particularly with recent new entrants into the tulip bulb industry and the dairy expansion. A specific challenge facing the tulip industry is restrictions on water takes for irrigation, which will become more so if tulip production is stepped up.

Southland is one of the main growing regions for winter vegetables and the only growing region for tulip bulbs. With New Zealand's growing population and pressure from larger urban centres on major growing hubs there may be an opportunity for the vegetable industry to expand in Southland. Opportunities for the tulip industry centre on developing new export markets in emerging economies and increasing demand for luxury goods. There is potential for the tulip growing area to expand over time, but it relies on the transfer of knowledge and expertise. Perennial crops, such as blueberries and blackcurrants, are grown on a small scale in Southland and may become a successful horticultural crop in the future. As perennial crops, these fruits carry a lower risk for excess nutrients when compared to root vegetables and tulip bulbs, and so they were not included as case studies in this research.

Image B14: Tulip bulb growing in Southland
Source: Tim Ellis

6.4. Environmental Issues Linked to Water Quality

The management regimes needed to grow vegetables and tulips use conventional cultivation practices and relatively high volumes of nitrogen fertiliser applied in the early stages of the crop growth. As a result, the loss of nitrogen for time the crop is in the ground is relatively high when compared with purely pastoral land uses. These horticultural crops are grown for a short period out of the full rotation length on any particular block of land. Over the full rotation the total average annual nitrogen loss for that block is lower than an annual average leaching rate from a specific crop in the year it is grown.

Horticulture New Zealand has produced *Erosion & Sediment Control Guidelines for Vegetable Production* and *Code of Practice for Nutrient Management* for its growers. These publications follow a risk based framework to minimise leaching loss by matching inputs to plant requirements and minimising the potential for the loss of soil particles that may contain phosphate. “Don’t Muddy the Waters” is a project to quantify the effectiveness of actions to reduce erosion and sediment loss from cultivated land that is run by Horticulture New Zealand together with regional councils, other industry groups, and the Ministry for Primary Industries. ‘Rootzone Reality’ is another jointly funded project that is looking at actual leaching under cropping rotations (through a fluxmeter network) to improve understanding, and potentially modelling, of nitrogen loss.

7. Forestry

Compiled by **Environment Southland** staff with contributions from Steve Chandler (Environmental Manager) **Rayonier Matariki Forests**, Graeme Manley (General Manager), **Southwood Export**.

Forestry in Southland is occurs through two main industries: plantation forestry, which is split into commercial plantation forestry and farm forestry, and indigenous forestry, which is harvested from sustainably managed native forests. The extent of these two industries is shown in Figure B29. Of the area in plantation forestry, commercial plantation forestry makes up 75 percent and farm forestry the remaining 25 percent. This section first briefly outlines indigenous forestry and farm forestry, and then focuses on commercial plantation forestry.

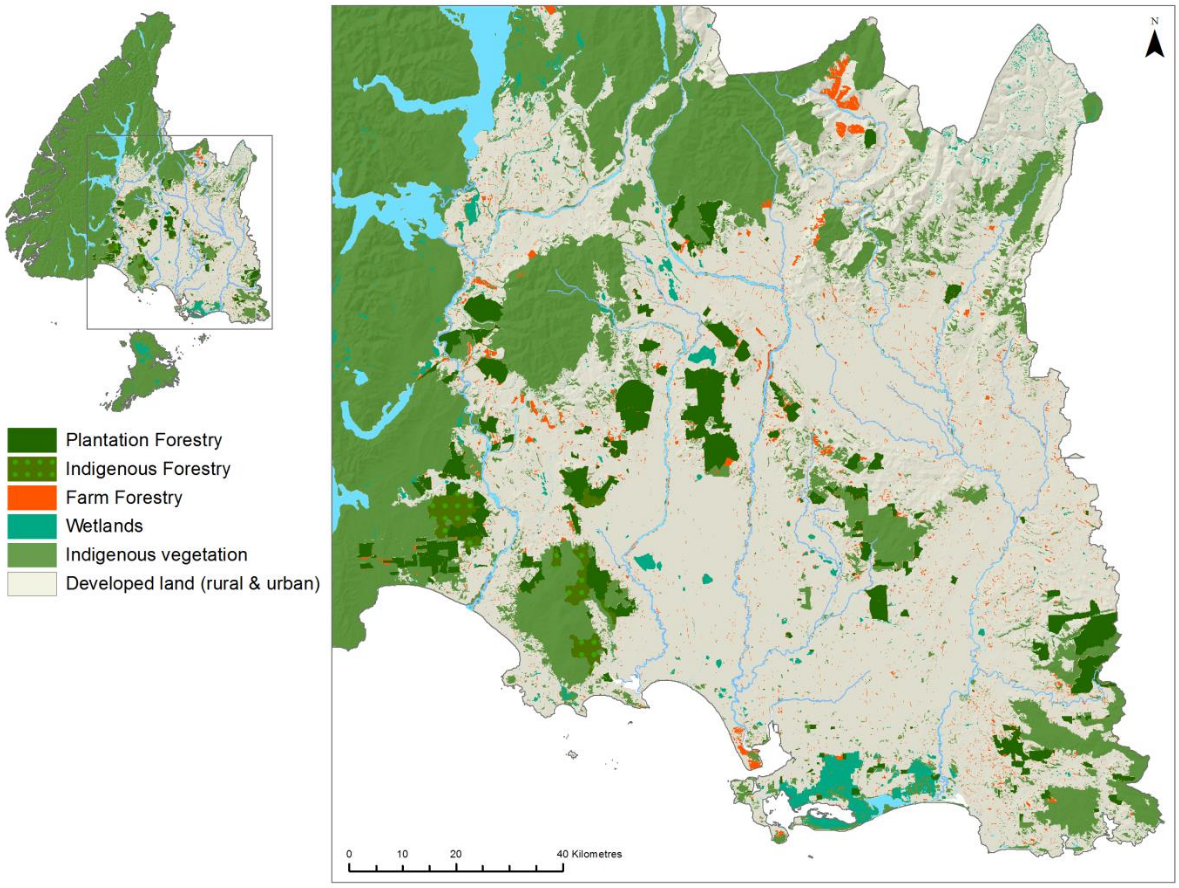

Figure B29: Plantation forestry in Southland 2015
Source: Pearson and Couldrey (2016)

7.1. Indigenous Forestry

Southland's forestry sector dates back to the early years of European settlement, where the logging of indigenous timber was once the core component of land settlement and development. The shape of the industry changed with a 1993 amendment to the Forests Act (1949) that moved indigenous harvesting regimes to a sustainable management basis[57]. Private forest owners are now required to have an approved sustainable management plan or permit. The Government also took the decision to cease harvesting timber from large areas of Crown land and permanently preserve these areas within the conservation estate. These changes led to the closure of many indigenous forest logging operations (Ledgard G. , 2013). The indigenous timber industry is now a small but important part of the forestry sector in Southland, producing a major proportion of high-value sawn timber for flooring, furniture, panelling and veneers (Ministry of Agriculture and Forestry, 2008).

There is an estimated 53,700 hectares of indigenous forest in Southland on privately owned land (Pearson & Couldrey, 2016), including land reserved for Māori under the 1906 South Island Landless natives Act (SILNA) and land adjoining the conservation estate but not areas under protective covenants. The indigenous forest estate is largely beech, and particularly silver beech. Timber is harvested from the Rowallan forest (located in the Waiau FMU), and the Woodlaw and Longwood forests (located in both the Waiau and Aparima FMUs) (Ledgard G. , 2013).

There is 12,250 hectares of indigenous forestry in Southland, but the majority of this area is not harvested. Instead a Sustainable Forest Management Plan allows for the harvest of native timber, while retaining the forest's natural values (MPI, 2013). There are three consents to harvest timber from this land equating to 26,323 m^3 per year as a permitted harvest, and 90 percent was silver beech) (MPI, 2014b). To put this volume in context, the total permitted indigenous harvest within New Zealand is just over 75,000 m^3; giving Southland one third of the total permitted harvest.

The largest consent holder of sustainable forest management permits for harvesting in Southland is Lindsay & Dixon Ltd., which is an integrated forest management and timber processing company, based in Tuatapere in western Southland (Ministry of Agriculture and Forestry, 2008). The company dates back to 1931 and is New Zealand's largest processor and marketer of indigenous timbers (Ministry of Agriculture and Forestry, 2008). This single company produces 80 percent of all sawmilled indigenous timber in New Zealand and exports to Japan, Australia and Malaysia (Hartley, 2013). Lindsay & Dixon mostly handle silver beech and their log supply is sourced from the Longwood and Rowallan forests. Their permissible annual harvest volume is 23,628 m^3 across all species, which is 1.8 percent of the forest stock. The remaining permissible annual harvest volume of 6,695 m^3 is administered by other companies.

7.2. Farm Forestry

Farm forestry is the growing of trees or woodlots on farms for various reasons including planting shelter belts, riparian buffers, retirement of non-productive pastoral land, or as a form of additional income. It usually occurs on the least productive areas of a farm and is often seen as a complementary to other farm enterprises. The majority of farm forestry in Southland is on drystock farms where there is a total of 20,500 hectares of exotic plantations. Dairy farms and arable farms also have 4,100 hectares of exotic forestry, largely in the form of shelter belts.

[57] These harvesting regimes remove less than the incremental growth in standing volume, and enhance the environmental values of the forest (Ministry of Agriculture and Forestry, 2008).

About 70 percent of farm forestry is small-scale (0-40 hectares), 20 percent are medium-scale (41-400 hectares) and 10 percent are large-scale (401-5,000 hectares) and likely to be on high country stations. The large proportion of smaller plantations or woodlots suggests that farm forestry tends to be either on less productive land or for other purposes than harvest, such as a shelter belt or riparian buffers. These woodlots make up three percent of the total forestry area in Southland. The medium and larger plantations are more likely to be grown for additional farm income.

Image B15: Macrocarpa shelter belt near Cosy Nook
Source: Simon Moran

The smaller-scale woodlots in steeper gullies may be uneconomic to harvest because their difficult location can create access issues (Steve Chandler, pers. comm., 2016). Woodlots provide benefits, such as improving stock welfare, and are often used for lambing or fawning on drystock farms and can greatly increase stock survival rates. They are also used to provide capital income for farm succession (Parnell Trost, pers. comm., 2015). Plantings can reduce surface water runoff by improving the infiltration capacity of compacted soils, and are used as buffers to filter nutrients from the pastoral areas of a farm (Dyck, 2003). In general, farm forestry is a viable option for mitigating nutrient losses within areas of the farm that are less productive. The species used for farm forestry are mostly radiata pine, with smaller plantations of eucalypt, cypress and Douglas fir. The larger areas of farm forestry are generally in hill country, possibly because the land is too steep for stock or other crops. The smaller areas are more spread out, but there is a definite trend around the rivers, indicating that farm forestry is being used for riparian barriers. The ratio of farm forestry to agricultural land is similar in each FMU.

7.3. Commercial Plantation Forestry

New commercial plantation forests were established in Southland in the 1920s and 1930s, and again from the 1960s to 1980s, as a result of the State Forest Service's programme to develop a large plantation resource based primarily on radiata pine. Douglas fir plantations go back to the early days of the establishment of plantation forest, with the species being used for sites less suited to radiata pine because of factors like high altitude and snow (Steve Chandler, pers. comm., 2016). The area of plantation forests in Southland increased steadily over the twentieth century from 445 hectares in 1900 to 17,300 hectares in 1970 (Ledgard G. , 2013).

Image B16: Eucalyptus forestry looking across to radiata pine on West Dome
Source: Graeme Manley

Up until the 1980s, the plantation forestry industry was highly regulated and new plantations were restricted to land not considered for agriculture (Business and Economic Research Limited, 2005). Deregulation of the industry during the 1980s saw the dis-establishment of the New Zealand Forest Service (previously the State Forest Service) and changes in ownership of many plantations (Business and Economic Research Limited, 2005). A number of grants and subsidies for forest development and tree planting were also removed. Despite these changes, the area of Southland's plantation forests grew rapidly after 1970 to reach 57,000 hectares in 1995, or 4.8 percent of all developed land in the region (Ledgard G. , 2013). Between 1993 and 1995 there were over 15,000 hectares of new plantings (Ledgard G., 2013), driven by the combination of lower land prices and higher log prices during these years.

The early 1990s saw an increase in the area of Douglas fir plantings, as land was bought up that was less suited to radiata pine and at a distance from markets, and eucalyptus species were also planted. The Eucalypts were primarily located in lowland areas and the foothills, generally within 100km of Invercargill, while the hardier Douglas fir were further inland at higher altitude catchments (Ledgard G., 2013). For good growth, eucalypts require higher quality land than radiata pine or Douglas fir (Graeme Manley, pers. comm., 2015). Sizeable Douglas fir plantings were established between 1995 and 2004, first by large-scale forestry owners, and then by small-scale owners (Ministry of Primary Industries, 2015e). When not carefully located, Douglas fir plantations come with a risk of wind-blown seed dispersal into surrounding areas (refer to Part B: Section 7.8.1).

Image B17: Eucalyptus forestry near Lilburn Valley
Source: Graeme Manley

Between 1990 and 2003, the volume of wood harvested from Southland's plantation forests doubled from 780,000 m^3 to 1,560,000 m^3, and processing capacity increased by around 800,000 m^3 (Business and Economic Research Limited, 2005). The extra processing capacity came from the establishment of the Dongwha New Zealand MDF (medium-density fibreboard) plant near Gore in 1993. Since 2005, the total commercial plantation forest area in Southland has declined by around 6,000 hectares (Millar, Keen, McDonald, & Gillingham, 2015), with some forestry land being converted to dairy.

At the end of June 2015, the area of exotic timber harvested for Southland, for the previous year, was 1,845 hectares (or 3.7%), out of a total area harvested annually for New Zealand of 50,219 hectares (Statistics New Zealand, 2016a). At the time Southland has a net stocked forest area[58] of 81,700 hectares (Ministry of Primary Industries, 2015e), so the area of harvested timber was equivalent to around 2.25 percent. Figure B30 shows the age of commercial forestry both throughout the country and specifically in Southland (but not the Otago/Southland wood supply region, which is explained further in Section 7.4).

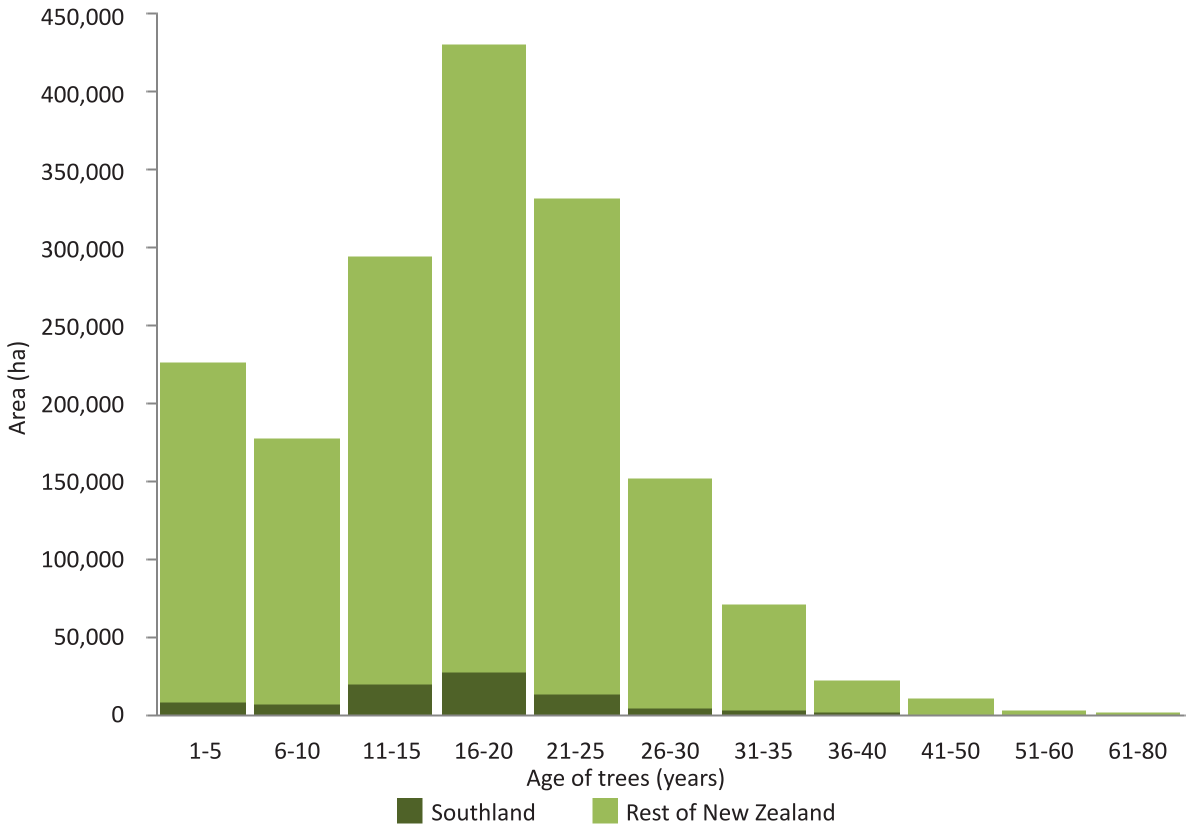

Figure B30: Age of commercial plantation forestry in Southland and New Zealand (2015)
Source: National Exotic Forest Description, 2015
Note: Southland's forest area is calculated through an addition of the three Territorial authorities areas - not the Otago/Southland wood supply region (see Section 7.4 Ownership and Management).

Around 40 percent of Southland's commercial plantation forestry estate is grown in large forestry blocks between 1,000 and 5,000 hectares. Medium-sized forestry blocks between 100 and 1,000 hectares made up 41 percent of the blocks identified, while the remaining 19 percent were less than 100 hectares in size.

The size classes are important because much of the large forestry blocks (1,000 – 5,000 ha) have been established before the 1970s and '80s and have already harvested their first rotation of crop. As such, there has already been a large investment in infrastructure and the established roading

[58] Net stocked forest area: The planted production forest area occupied by trees excluding mappable gaps such as landings, roads and other unstocked areas (National Exotic Forest Description, 2015).

network lowers the overall cost of extraction of the second rotation. In contrast, the small forest classes typically do not have established internal roading and are instead harvested in a piecemeal manner that incorporates forest roading as the harvesting activity progresses. For a proportion of smaller blocks this capital cost may make extraction uneconomic or only viable during a log price spike. (Millar, Keen, McDonald, & Gillingham, 2015).

Figure B31 shows the distribution of forestry blocks by size in Southland (in 2015) based on a range of GIS mapping exercises (Millar, Keen, McDonald, & Gillingham, 2015).

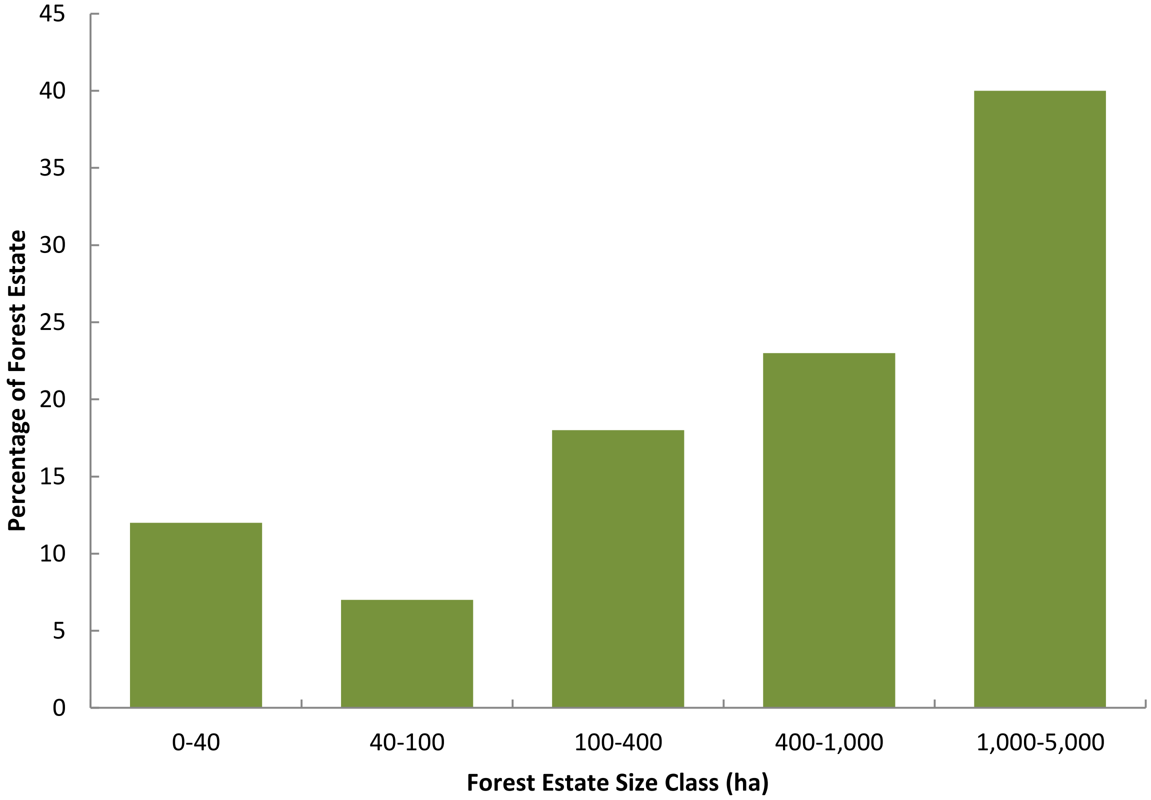

Figure B31: Forest size class in Southland as a proportion of forest estate
Source: Millar et al., 2015

7.4. Ownership and Management

New Zealand's forestry sector is divided into wood supply regions. Southland is part of the Otago/Southland wood supply region and makes up 40 percent of Otago/Southland's planted production forest area. Figure B32 shows the share of total area by species in both Southland and the Otago/Southland wood supply region in 2015.

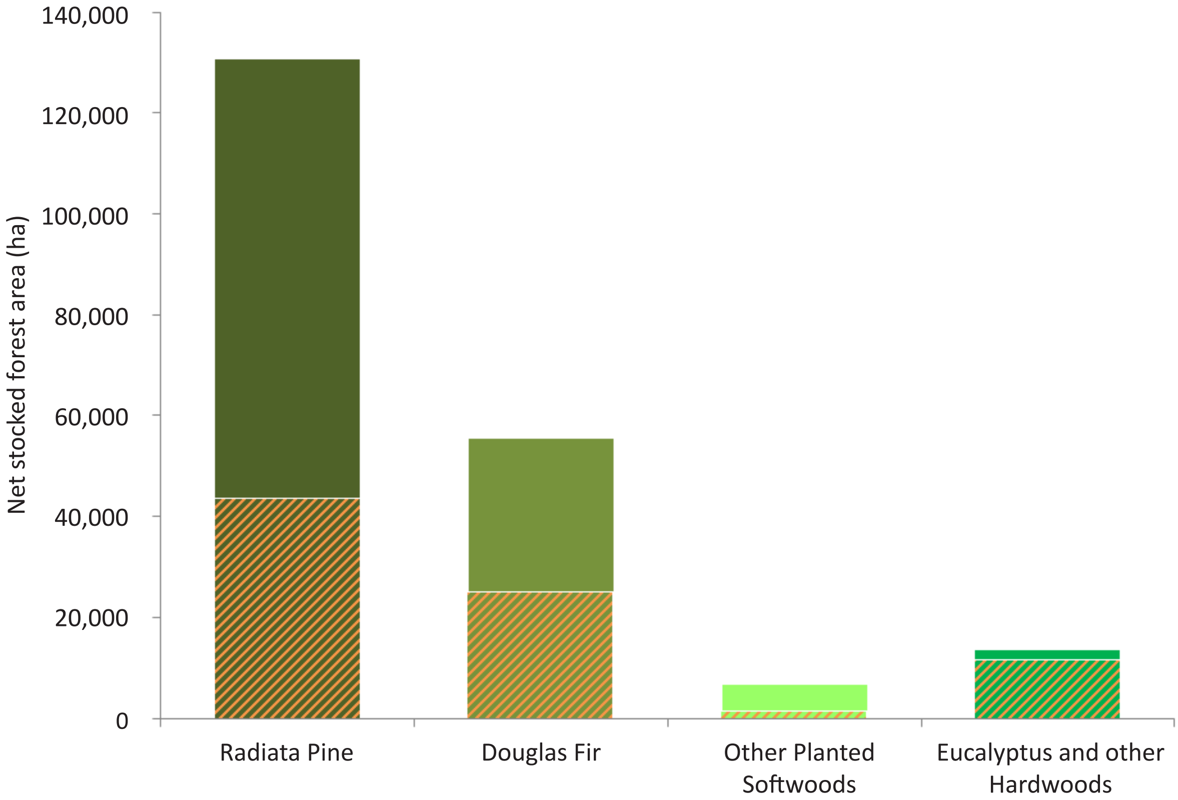

Figure B32: Total area of commercial forestry species in Southland and Otago/Southland in 2015
Note: The area in Southland is the hashed orange block of the Otago/Southland wood supply region as a whole.
Source: National Exotic Forest Description, 2015

The majority of forestry land (around 76%) is in blocks of over 400 hectares and these blocks are either owned or managed by large corporate forestry companies: Earnslaw One Limited, Rayonier New Zealand Limited/Matariki Forest, Craigpine Limited, and Southland Plantation Forest Company of New Zealand Limited, and Southwood Export Limited and clients.

Earnslaw One Ltd. owns and manages 29,000 hectares of forest estate in Otago/Southland, of which 23,500 hectares is commercial forest. The remaining 5,500 hectares are in remnant bush reserves, or are unsuitable for tree growth. This forest is used for other activities such as freshwater crayfish fisheries, frost zones, riparian areas and power line corridors. Douglas fir dominates the planting and re-planting regime of Earnslaw One Ltd. at 15,000 hectares of the net stocked area. While there is also 6,000 hectares of radiata pine, 1,500 hectares of Corsican pine and the remaining 1,000 hectares are in minor exotic species (such as spruce, larch, and cedars) (Ministry of Agriculture and Forestry, 2008).

Rayonier New Zealand Ltd. manages the 39,200 hectares of Matariki Forests estate in Otago/Southland, of which 30,500 hectares are currently in planted forest (net stocked area). Currently Rayonier is harvesting between 400,000 and 420,000 cubic metres of predominantly radiata pine logs annually. Rayonier prefers to sell wood through an open tender process rather than engaging in long term contracts or direct sales to overseas customers. This approach means the immediate purchasers of Rayonier's logs are domestic customers and sawmillers (Ministry of Agriculture and Forestry, 2008).

Craigpine Timber Ltd. owns an estate comprising of eight forests and 3,800 hectares of freehold land in Southland. The net stocked area is 3,000 hectares. Small holdings of Douglas fir and macrocarpa have been established (less than 100 hectares in total). The remaining 800 hectares are maintained in indigenous bush covenants. Craigpine Timber harvests around 20,000 tonnes of radiata pine each year. This yield is expected to be maintained until 2034, after which time it is set to triple (Ministry of Agriculture and Forestry, 2008).

Southwood Export Ltd. manages 10,500 hectares of eucalypt plantation forests on behalf of Southland Plantation Forest Company of New Zealand Ltd., along with 4,000 hectares of remnant indigenous bush, wetlands, covenanted areas and access roads. The estate is made up of 40 individual forests in Otago/Southland where planting began in 1992. Harvesting operations started in 2004, and the first shipment of plantation grown hardwood chip was exported from Bluff in March 2005. The sustainable long-term average harvest is 250,000 cubic metres each year. Southwood Export Ltd. also own or manage 2,200 hectares of forest, mostly eucalypts, on behalf of other clients (Ministry of Agriculture and Forestry, 2008).

Since 2011, there have been increases in both new planting areas and re-planting areas in Southland after only limited planting between 2007 and 2010 (Statistics New Zealand, 2016a). This change can is evident in Figure B33, where trees from 6 to 10 years of age were planted between 2007 and 2010.

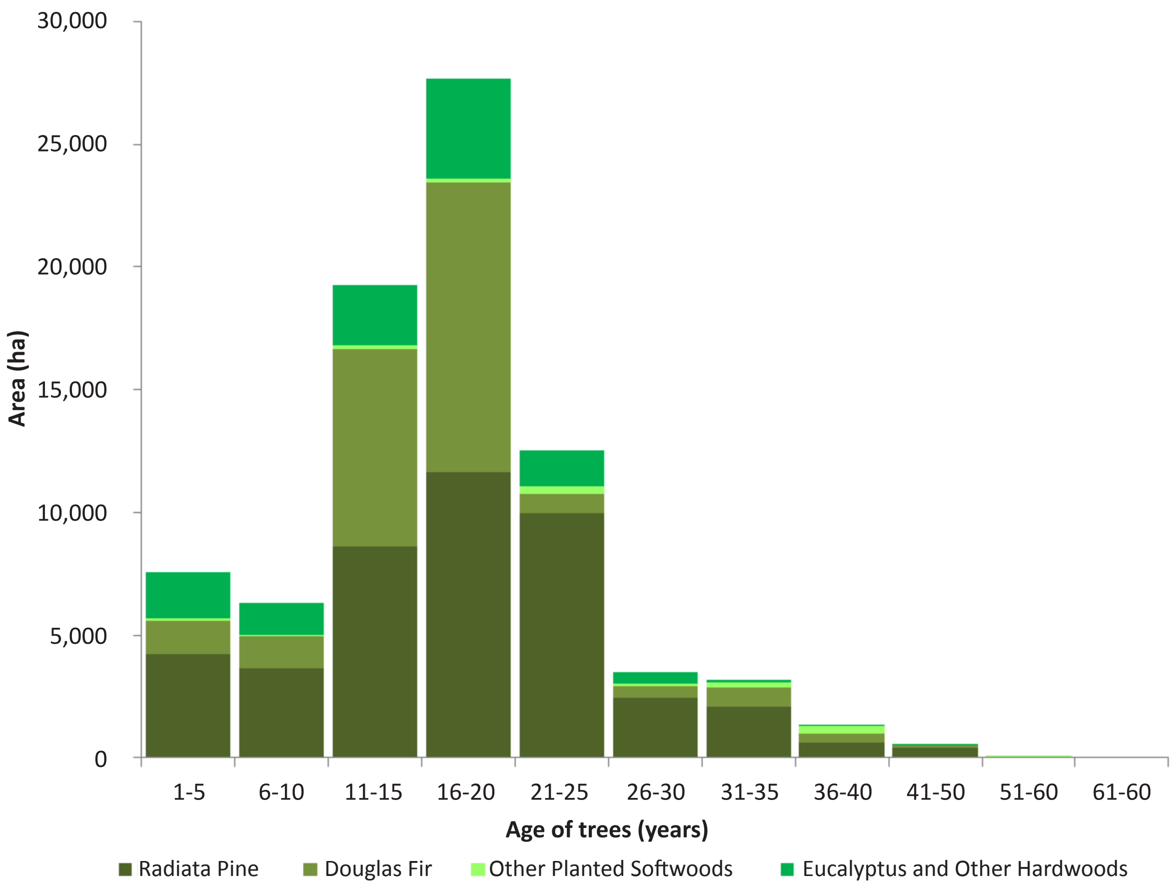

Figure B33: Age of commercial plantation forestry in Southland (2015)
Source: National Exotic Forest Description, 2015

7.5. Processing and Export

Although plantation forestry (excluding farm forestry) makes up just 6.7 percent of the developed land area in Southland, commercially it is the region's fifth largest export by value. Overall, the value of forestry exports has been increasing in recent years (8.8% if farm forestry is included). In 2013 forestry exports were valued at $138 million, up from $123 million in 2011 and $90 million in 2003 (Business and Economic Research Limited, 2014). In general, Southland's forestry estate has good forestry infrastructure and a medium-scale timber processing industry (Millar, Keen, McDonald, & Gillingham, 2015).

An essential part of the forestry infrastructure is South Port at Bluff. From 2006 to 2014 the export of logs increased by around 400 percent – the exception was in 2012 when log exports declined markedly (Millar, Keen, McDonald, & Gillingham, 2015). The export of sawn timber through South Port has fluctuated during this period, peaking in 2012 and at its lowest point in 2008. Production of hardwood chip has also had a generally increasing trend with some fluctuations. Table B13 and Figure B34 show export volumes of logs, sawn timber and hardwood chip from 2006 to 2014.

Table B13: Export volumes through South Port 2006 to 2014

Year to end March	Export logs (m^3)	Sawn timber (m^3)	Hardwood chip (m^3) (2.04 x bone dry tonnes)	Hardwood chip (bone dry tonnes)
2006	74,183	110,872	81,454	40,727
2007	91,816	70,027	118,416	59,208
2008	103,435	59,981	121,616	60,808
2009	101,371	81,169	78,018	39,009
2010	269,488	102,433	144,864	72,432
2011	301,357	115,261	180,264	90,132
2012	208,938	140,515	161,260	80,630
2013	314,743	123,455	163,886	81,943
2014	395,503	110,050	157,744	78,872

Source: Adapted from Millar et al. 2015 from MPI Quarterly Trade Statistics
Note: Additional volumes were exported through Port Chalmers in Dunedin.

Log export volumes have increased markedly over the 2006 to 2014 period, more than quadrupling in the eight years from 2007 to 2014. By comparison, sawn timber and hardwood chip exports have remained reasonably consistent with various peaks and troughs over time.

In addition to South Port, there is a medium-scale forestry processing industry in Southland (Millar, Keen, McDonald, & Gillingham, 2015) made up of log processors, a chipping facility and a fibreboard factory. There two large log processors, Craigpine Timber Ltd. (near Winton) and Niagara (near Invercargill), that each process around 200,000 tonnes of logs per year into sawn timber. There are also a number of smaller sawmills around the region. Table B14 shows the main log sawmills in Southland and maximum tonnes of logs processed into sawn timber each year. Southland also processed a proportion of the Otago timber harvest (around 300,000m^3 per year) in the early to mid-2000s (Parnell Trost, pers. comm., 2015).

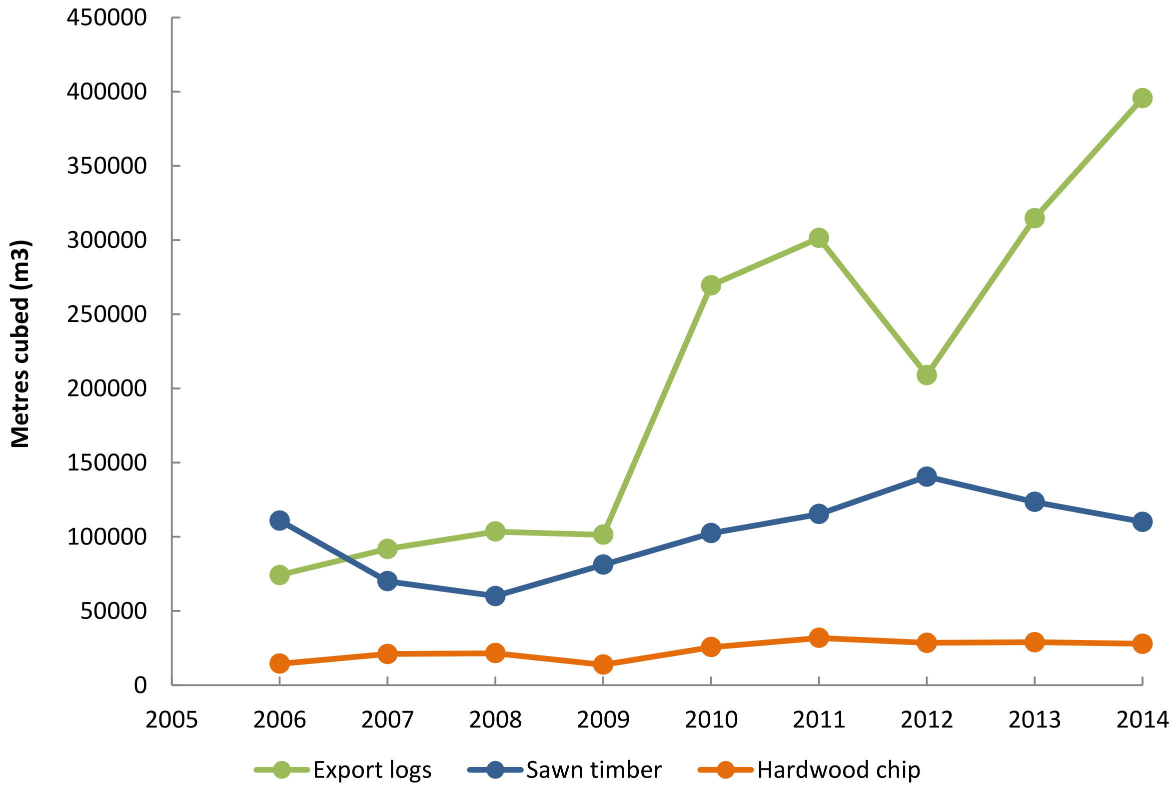

Figure B34: Export volumes through South Port 2006 to 2014

Table B14: Main log processors in Southland

Processor	Location	Tonnes of logs per year processed into sawn timber
Craigpine Timber Ltd.	Winton	200,000 – 250,000
Niagara Sawmilling Co. Ltd.	Kennington	180,000 – 200,000
Pankhurst Sawmilling Ltd.	Riverton	40,000
Ngahere Sawmilling Co. Ltd.	Matāura	<20,000
Lindsay and Dixon Ltd.	Tuatapere	<20,000
Findlater Sawmilling Ltd.	Winton	<20,000
Beven West Sawmilling Ltd.	Branxholme	<20,000

Source: Millar, Keen, McDonald, & Gillingham, 2015.

Beyond the log processors, Dongwha New Zealand's MDF plant typically processes between 350,000 and 390,000 tonnes of chip to produce medium-density fibreboard (MDF), with roughly two thirds of production coming from logs and the remainder from sawmill chip residue. There is also a chipping facility at Awarua (near Invercargill) owned by Southwood Export Ltd. In 2016, around 340,000 tonnes of hardwood eucalyptus logs were chipped at the facility for export to Japanese pulp and paper manufacturers (Graeme Manley, pers. comm., 2017).

In recent years, there have been closures of Southland's smaller processing facilities – Southern Cross Forests and Southland Veneers. While the number of processing plants has decreased, the larger facilities have continued to invest in increasing processing capacity and diversifying production (Parnell Trost, pers. comm., 2015).

7.6. Employment

The forestry sector contributes to employment in Southland. Employment in forestry between 2005 and 2014 has remained roughly constant in Gore District at around 150 employees, declined in Invercargill from just over 300 to around 170 employees, and fluctuated in Southland District at around 450 employees (Statistics New Zealand, 2012)

The Otago/Southland wood supply region is the second largest area of planted forest after the Central North Island (Ministry for Primary Industries, 2015c). Roundwood[59] removal statistics show that in 2015 the Otago/Southland wood supply region contributed 7.2 percent of New Zealand's total roundwood removals (Ministry for Primary Industries, 2015d). Otago/Southland lies fifth behind the Central North Island (40.6%), East Coast/Hawke's Bay (16.2%), Northland (14.1%), and Nelson/Marlborough (8.5%). Otago/Southland's share of total roundwood removals for New Zealand has been reasonably consistent from 2003 to 2015, ranging from 6.7 percent to 7.7 percent over this time. The volume of wood in Southland available for removal is expected to increase substantially by 2020.

7.7. Main features in Southland and Future Outlook

The Otago/Southland wood supply region is New Zealand's most diverse in terms of species grown. This wood supply region has New Zealand's largest Douglas fir plantation, the largest area planted in eucalypts species, the second largest area planted in cypress species, and the second largest area planted in other softwoods (other than radiata pine, Douglas fir and cypresses) (Ministry for Primary Industries, 2015c).

In comparison to other parts of New Zealand, the forestry resource in Southland is relatively young, meaning the sector likely to grow over the coming decades as the current stock is harvested (Ministry of Agriculture and Forestry, 2009).

As mentioned above, wood flows from the Otago/Southland wood supply region are expected to increase in coming years (Millar, Keen, McDonald, & Gillingham, 2015). This growth will increase the size and significance of the forestry sector in Southland as a contributor to the regional economy (all other things being equal). In 2015 an estimated 1 million tonnes of logs was harvested annually in Southland, which is expected to rise to 1.2 million tonnes by 2019 and 1.55 million tonnes by 2039. Implementation of the National Policy Statement for Freshwater Management (2017) in Southland over the coming decades may increase interest in forestry because of its lower nutrient losses in comparison to agriculture.

[59] Roundwood equivalent is a theoretical measurement giving the total amount of roundwood necessary for the production of one unit of a stated forestry product with existing technology as if roundwood were used as a raw material; no allowance is made for the use of the residues in the manufacture of the product (Parnell Trost, pers. comm., 2015).

Image B18: Harvesting in Castledowns Forest
Source: Steve Chandler

Southland's forestry and wood processing facilities generate around 300,000 tonnes of potential wood fuel per year. Growth in wood energy is a potential opportunity for the forestry sector in Southland for the future. For businesses reliant on fossil fuels, wood energy can be a cleaner, more efficient heating source, meet stricter air quality standards, and withstand carbon pricing influences (EIS Energy, 2011). The Wood Energy South Project was set up to lower energy-related carbon emissions, improve air quality, and demonstrate the lower costs and life cycle benefits of boilers fuelled using local waste wood (Wood Energy South, n.d.a; Wood Energy South, n.d.b). In considering the potential of wood energy security of supply is important. Southland's corporate forestry estate is both sizeable and stable, which allows for reliable wood flow supply to the wood processing industry. These wood flows are predicted to increase considerably in the future.

Eucalyptus has good potential for wood energy production. The wood has a higher density than radiata pine, suitable chemical characteristics, low moisture content, and can be harvested year-round. Eucalyptus also dries more quickly than Pinus radiata so can have lower transport costs. The biggest limitations are the availability of forestry land at a reasonable cost and distance, with wood energy forests needing to be located within 50 – 80 kilometres of the end user. In Southland, most large end users are located in areas of high value agricultural land. Some opportunities for this type of development may exist further afield in the hills to the east and west of Invercargill (Millar, Keen, McDonald, & Gillingham, 2015).

The fertility and growth of a forestry rotation depends on nutrient recycling from the harvest residues of the previous rotation. If an increased proportion of the residues are used – for example for renewable energy – then this may be an issue for some forestry plantations in the future, as there may be a need for fertiliser for further rotations. This issue means that the use of inputs in the production system will be higher than they currently are (Parnell Trost, pers. comm., 2015).

Land prices will have a major effect on how much land in Southland is in forestry in the future, and also where this land is located. If carbon prices rise again to between $20 and $30, forestry may be seen moving further away from main transport centres than now, as the financial gains outweigh the transport costs (Steve Chandler, pers. comm., 2015).

7.8. Environmental Issues Linked to Water Quality

Nitrogen losses from forestry vary depending on the history of the land, management of the forest, and time since planting (Monaghan, Semadeni-Davies, Muirhead, Elliott, & Shankar, 2010). Generally, a change in land use to forestry decreases nutrient losses from the land because it decreases fertiliser inputs as well as rates of nitrogen fixation and soil erosion, and it removes grazing animals (Monaghan, Semadeni-Davies, Muirhead, Elliott, & Shankar, 2010). Nutrient losses can increase for a time after harvest.

An Environment Court case found that radiata pine planted on improved pasture in the Lake Taupo catchment may lose between 8 and 12 kg N/ha/year (Monaghan, Semadeni-Davies, Muirhead, Elliott, & Shankar, 2010). These rates are likely to be lower in Southland, at around 2 kg N/ha/year (Ledgard G. , 2014); because of the difference in soil types (pumice soils are dominant near Taupo). The type of harvest techniques can be used to mitigate these sediment and nutrient losses, but this is a viable option only sometimes for Douglas fir and not usually for radiata pine. (Steve Chandler, pers. comm., 2015). Forestry blocks can also be sources of phosphorus loss to water. Phosphorus losses from pine catchments are usually higher than those from native forest catchment but lower than losses from pasture (Monaghan, Semadeni-Davies, Muirhead, Elliott, & Shankar, 2010).

Forestry operations can expose soil and increase losses of suspended sediment, particularly during afforestation and harvesting. During these times, shrub clearance, loosening of soil and infrastructure works can make the soil vulnerable to erosion from rainfall and wind, and increase the risk of large sediment loads to enter water bodies (Ledgard G. , 2013). In Southland, much of the forestry estate is located within hill country catchments, which increases the risk of sediment in run-off to water bodies.

Trees also use a lot of water for growth. Extensive plantation forestry, both commercial and farm forestry can change the hydrology of a catchment through their ability to draw water out of the soil. This can lead to dry ephemeral water bodies or stream beds where water once flowed. Another way trees can change the hydrology of a catchment is through the harvest residue or 'slash' being washed in to water bodies and damming or restricting the flow. This can lead to downstream problems; for example, the risk of flood or problems at the source (turbulence, high velocities or hidden obstacles underwater).

Afforestation helps with the evaporation of rainfall, reducing the amount of water falling on land and so runoff – it can reduce peak flood flows in catchments by up to 50 percent (Davie & Fahey, 2005). In intercepting rainfall and taking up water from the land, afforestation can change the flow of water in a catchment and the amount available downstream. Forested catchments may benefit aquatic ecosystems through regulation of temperature and light. Aquatic and semi-aquatic insects prefer cool, dark shaded streams with navigable rocks. The lower water temperatures also inhibit macroalgal and macrophyte growth, and decrease the likelihood of algal blooms (the rapid growth of algae causing discolouration of the water). Forests also act as a nutrient filter, moderating the effects of run-off from heavy rainfall (Steve Chandler, pers. comm., 2015).

When alongside agriculture, forestry creates beneficial micro-climates for pasture growth and stock health. Similar to shelter-belts, they act as a climatic stabiliser, reducing wind intensity, precipitation (rainfall and snow), and increasing temperatures on the leeward (protected) side.

Over the whole rotation, the direct effect of forestry on water quality is largely minimal. Sediment loss is the major issue, which is focused to certain times within the rotation, particularly construction of infrastructure (roads) and harvest. When considered over a rotation period of 25 – 35 years for radiata pine and 15 – 20 years for eucalypts its effects are less in terms of kilograms per year.

7.8.1. Wilding Tree Control

Controlling wilding trees on neighbouring properties is a major challenge for the forestry industry in Southland, and comes at a considerable cost. This issue is particularly relevant for Douglas fir. The spread of wilding conifers is influenced by a number of factors, including the species of tree, position and shape of the source population, wind strength and direction, frost and drought, the surrounding vegetation type, and land management practices (Ministry for Primary Industries, 2014).

Under the Southland District Plan, resource users must adopt the best practicable option to avoid or mitigate the effects of the spread of wilding pines, and the planting of Douglas fir is a restricted discretionary activity (i.e. it requires a resource consent) within the Mountain Resource Area. A number of the applications to plant Douglas fir in Southland have consent conditions to control wildings to a radius of up to several kilometres.

Forest owners who are members of the Forest Stewardship Council are required to be good neighbours, which includes controlling wilding tree spread. The New Zealand Wilding Conifer Management Strategy includes an action to develop best practice regional pest management plan rules, which address wilding conifer spread across boundaries without capturing appropriate plantings (Ministry for Primary Industries, 2014).

Sheep grazing has been identified as one method of control for wilding conifers (Froude, 2011). The success of grazing depends on palatability of the grass species. Whether grazing is feasible or not can depend on the altitude of the land – where sheep have to be mob stocked to eat the trees, there are likely to be other adverse effects as the land is above 700 m above mean sea level (Ken Murray, pers. comm., 2015).

Part C: Farm Case Studies

Part C reports on the survey and modelling of 95 case study farms in Southland. It builds on the outline of Southland in **Part A** and the overview of the region's agricultural and forestry sectors in **Part B**.

Part C is made up of six main sections:

Section 1 outlines the general approach to the farm selection, survey and modelling, and mitigation scenarios for the agriculture sector;

Sections 2 to 5 describe the specific methods each agricultural industry used and summarise their results; and

Section 6 describes **The Southland Economic Model for Fresh Water**.

1. General Approach

The purpose of this research was to develop information on the impacts on farm profitability of managing more nutrient losses within production systems so that this information will be available during community processes to set limits for fresh water in Southland. Specifically, this research focused on 95 farms across the region and investigated existing nutrient losses and actions (or mitigations) to further reduce nutrient losses. As outlined in **Part B** of this report, there are five main agricultural industries in Southland: dairy, sheep and beef, deer, arable, and horticulture. Within these industries there are thousands of farms, each with their own management systems and environmental conditions (particularly climate, topography and soils). The relationship between nutrient losses and profitability will be different for each farm.

This section describes the general approach used in this research, including guiding principles. This research was undertaken between 2014 and 2016. During this time, Environment Southland developed the physiographic zones (refer to Part A, Section 2.4) and notified the proposed Southland Water and Land Plan.

This research was built on similar work done elsewhere in New Zealand and it has taken a number of further steps. It was the first time research has included farms from across a region, and it is one of the largest farm analyses of its type to date. It was the first time these industry groups have all collectively been involved in research of this type. It was also the first time that specific phosphorus mitigations were modelled by these industry groups.

There were two guiding principles that shaped this research. First, the research used Southland farms and covered the areas where each industry occurs across the region, rather than being limited to particular localities. The main reasons were the variation in Southland's climate and soils (outlined in **Part A**) and the importance for farmers to know that farms were included from their local area. This coverage was largely achieved for dairy, sheep and beef, and horticulture and to a lesser extent for deer and arable because of the more limited resources available to these industries.

Second, the research was tailored to reflect the nature of each industry's production systems. While real efforts were made for the research to be roughly consistent across the industries, it was more important that the methods used were relevant to that industry. During the course of the research it became increasingly clear that there is no "one size fits all" when it comes to methodology, and what made sense for one industry was not necessarily the case for another. In many respects, complete consistency was always going to be unrealistic because of the diversity in farm production systems between industries.

In essence, the general approach was to develop a set of case studies for each industry based on information for farms across Southland. Case studies were a mix of quantitative and qualitative data and allowed multiple factors to be explored within a real world context. This approach allowed a range of different farm characteristics to be captured and was the most efficient way to cover as much of the diversity within each industry as possible. A statistically robust sample was not possible in this research because of the large number of farms that would be required and the time and effort needed for each farm[60]. This case study approach is similar to that used elsewhere in New Zealand and followed the basic process described below.

1.1. Farm Selection

The first step was to estimate the total number of case study farms needed for each industry, based on similar research done elsewhere in New Zealand, and each industry's area of agricultural land in Southland and its relative nutrient losses (using existing knowledge). Originally, a total of 97 case studies were planned as follows: 40 sheep and beef farms, seven deer farms, 40 dairy farms, three arable farms, three dairy support farms, and four horticultural growers. However, the eventual total was 95 case studies as follows: 39 sheep and beef farms, seven deer farms, 41 dairy farms, three arable farms, one arable dairy support farm, and four horticultural growers. Dairy support was also captured within the sheep and beef, deer, and dairy farms.

For both the dairy and the sheep and beef industries, the case studies were divided between the four FMUs with large areas of developed land based on the proportion of each industry's land area in an FMU. Table C1 shows the proportion of industry land in Southland within each FMU and the final number of case study farms included in this research by FMU[61]. For example, 19% of sheep and beef land area is in the Waiau and nine out of the 40 original case study farms (22.5%) were in the Waiau.

[60] The following example illustrates this point – if there are 4,000 farms in Southland then a statistical sample with a margin of error of 5% would have required a sample size of around 350 farms, with each farm taking up to 2 weeks to survey, model and write-up, or a total of 13 years effort. It is difficult to determine exactly how many farms there are because one farm may include more than one property.

[61] The table gives estimates of industry land area from the Southland Land Use Map 2015, which is more precise than the knowledge that existed when this exercise was carried out in 2014.

Table C1: Distribution of dairy and sheep and beef case study farms

Industry	Sheep and Beef			Dairy		
	Land Use	Case Studies		Land Use	Case Studies	
	% of land in region	No. of farms	% of total	% of land in region	No. of farms	% of total
Waiau	19%	9	23%	7%	3	7%
Aparima	9%	7	18%	22%	11	27%
Ōreti	20%	8	21%	38%	13	32%
Matāura	52%	15	38%	33%	14	34%
Total	**100%**	**39**	**100%**	**100%**	**41**	**100%**

For dairy, and sheep and beef, the number of case studies within each FMU was then divided into broad categories based on relevant environmental conditions. For sheep and beef, these conditions were slope and soil drainage (as indicated by Land Use Capability classifications) and rainfall. For dairy, the conditions were soil drainage and rainfall. The slope category used for the sheep and beef industry was not as relevant for the dairy industry, which usually occurs on flat to rolling land in Southland. The use of the broad categories gave an opportunity to investigate other farm characteristics within each category. The sheep and beef farms were primarily selected from the B+LNZ Economic Service Sheep and Beef Farm Survey; the dairy farms were primarily selected from DairyNZ's Baseline project.

For the other industries, the case studies were distributed in the areas they occur across the region rather than by FMU. For the deer industry, the farms were self-selected and split by majority deer and specialist deer. For the arable industry, the farms were chosen from the Foundation for Arable Research's database and covered a range of arable farm systems. For horticulture, there are only a handful of vegetable growers and tulip bulb growers and the case studies captured a large proportion of the industry. The farm selection process for each industry is described in the relevant sections of **Part C**.

1.2. Survey and Modelling

The next steps were to survey the selected farms to collect their environmental and farm management information and to use this information to model each farm in OVERSEER[62] version 6.2.0 (the newest version available at time of modelling) and complete financial analyses. OVERSEER was designed for testing the relative effects of possible changes in farm management on nutrient losses from a farm, which is how it was used in this research, and there are few alternatives.

All of the farms were surveyed through farm visits, except for horticulture, where growers were surveyed using an email questionnaire and follow-up telephone calls. The dairy industry used two teams of people – one team for the surveying and another team for the modelling. Drystock, arable and horticulture each used one person for all of its survey and modelling of the farms. Both approaches have advantages and disadvantages: a team of people is helpful for task completion and specialisation, while using the same person for surveying and modelling is useful for in-depth

[62] Detailed information on OVERSEER can be found at:
http://www.OVERSEER.co.nz/Portals/0/Release%20notes/Getting%20Started%20guide%20Oct%202013.pdf

knowledge. Dairy and horticulture focused on the collection of quantitative information while drystock and arable collected both quantitative and qualitative information. The farm management information included financial data for all of the farms except arable, which relied upon Ministry for Primary Industries farm monitoring data[63].

The OVERSEER modelling and financial analyses occurred in two stages. First, a base file was created for each farm for its current or baseline performance. Second, the settings were changed on the base file to simulate different mitigation scenarios. This step was repeated to build up each case study. All of the modelling was done following OVERSEER Best Practice Input Standards. All OVERSEER results are reported by a farm's total hectares because it is this area of a farm that is relevant for nutrient losses.

Alongside the OVERSEER modelling, different types of financial analyses were used to understand the impacts of the mitigations on profitability. For dairy and drystock, each farm was modelled simultaneously in OVERSEER and FARMAX[64] (a computer software programme designed for pastoral farming that estimates the feasibility of the physical farm system and farm profitability) to make sure the feed demand and supply balanced and that the farm still worked as a production system. Profitability for the drystock industries was reported on profitability using EBITR; profitability for the dairy industry was reported on profitability using operating profit or EBIT. Interest and rent are both costs of capital used in the business – EBIT and EBITR are comparable where rent is zero. Arable and horticulture used financial analyses and profitability measures relevant to their industries, in particular gross margins and cash operating surplus. The farm's financial results are reported by its effective hectares because it is this 'productive' area of a farm that is relevant for profitability.

1.3. Mitigation Scenarios

The mitigations modelled in the case studies were selected from a much wider range of mitigations that are available for reducing nutrient losses and they were chosen before the notification of the proposed Southland Water and Land Plan (2016). Of the mitigations that are relevant to farms in Southland: some are assumed in OVERSEER as already being used on-farm (e.g. timing and application rates for fertiliser); some are able to be modelled in OVERSEER; and some are neither assumed, nor able to be modelled, in OVERSEER but are potentially effective in reducing nutrient losses. The estimates of nutrient losses will result in different water quality outcomes depending on where they occur within the landscape.

More comprehensive lists of the mitigations that are relevant in Southland are available, such as the Agresearch report *Management practices and mitigation options for reducing contaminant losses from land to water* (Monaghan, 2016). Not all mitigations are relevant to all farms and their use needs to be well understood within the context of where and how a farm sits in the landscape (i.e. the natural underlying processes occurring in the land and water and the nutrient flowpaths).

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[63] MPI last ran the Farm Monitoring Programme in 2012 and it has since been replaced by partnerships with Beef+LambNZ and DairyNZ. MPI has a contract to access anonymised data for analysis within the Ministry, as required (http://www.mpi.govt.nz/news-and-resources/open-data-and-forecasting/agriculture/)

[64] Information about Farmax can be found at: http://www.farmax.co.nz/

Only those mitigations that can be modelled in OVERSEER were used in this research and each industry took a different approach to the mitigation scenarios. All industries except dairy modelled individual mitigations and reported on the change in nutrient losses and profitability. The dairy industry used a farm system approach that modelled increasing levels of mitigations aimed at achieving specified targets for nutrient reduction, and was similar to their modelling done in other regions in New Zealand. Drystock modelled a set of mitigations for each case study while dairy and arable modelled mitigations for nitrogen and for phosphorus in turn. Horticulture modelled nitrogen mitigations only.

Many of the mitigations that are either assumed or are unable to be modelled in OVERSEER have been identified through various industry and regional council initiatives as good management practices (for example, *Industry-Agreed Good Management Practices Relating to Water Quality*, 2015). Qualitiative information on the level of good management practices already implemented was collected by all industries except dairy (dairy farms are required to meet their industry's standards for good management practices under the Water Accord). Overall, the research found a wide range in the use of good management practices in Southland but this information is not reported because these practices were not necessarily relevant for all farms.

Some of these good management practices are likely to be the source of 'win-wins' – where a mitigation reduces a farm's nutrient loss and increases its profitability. However, these win-wins are often based on production systems moving towards an optimum level most of the time, which is challenging, particularly in a world of increasing change.

OVERSEER is valuable for showing relative changes in a farm's nutrient losses from different management practices. OVERSEER models dairying and nitrogen losses well but is more challenging when used for other industries and phosphorus loss. A high proportion of phosphorus is lost at locations on a farm where drainage occurs in channels from across a larger area, such as swales and gullies, but these areas are unable to be specifically modelled in OVERSEER. There is a growing body of research (nationally and internationally) that indicates a significant contribution of phosphorus to streams from groundwater (Gray, Wheeler, McDowell, & Watkins, 2016). The mitigations were modelled in a more generic way than they would be 'on the ground' because of the need to work within the constraints of the model.

Although a relatively large number of farms were included in this research, care should be taken when interpreting measures such as simple means (averages) and medians. On their own, each case study farm is indicative of farms of its type and with similar environmental conditions – and other farms will have similar characteristics to one or more of the case studies. As a set, each industry's case studies are a guide for its likely range of baseline nutrient losses and the effectiveness of mitigations and their impacts on profitability.

2. Drystock (Sheep, Beef Cattle, and Deer)

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Summary Points

Drystock farms cover a wide range of topography, soils, livestock species and classes, and production systems. The 46 case study farms reflected this diversity and are largely indicative of drystock farming across Southland.

Three of the 39 sheep and beef farms surveyed were unable to be modelled in OVERSEER because of the nature of these farms. Two of these farms included relatively large areas of crop (over 20% of the farm's effective area).

The remaining 36 sheep and beef farms had baseline nitrogen losses of 5 – 37 kg N/ha/year: two-thirds of the farms had 15 kg N/ha/year or less and one-third had more than 15 kg N/ha/year.

The seven deer farms had baseline nitrogen losses of 9 – 50 kg N/ha/year. Four of the sheep and beef farms included a deer enterprise and these farms had baseline nitrogen losses of 10 – 15 kg N/ha/year.

The sheep and beef farms had baseline phosphorus losses of 0.2 – 1.4 kg P/ha/year. The deer farms had baseline phosphorus losses of 0.5 – 2.5 kg P/ha/year.

Profitability (measured using EBITR / effective hectare) for the 36 sheep and beef farms averaged $599, with a median of $485. The seven deer farms averaged $476 with a median of $395. There was no clear relationship between profitability and baseline nutrient losses for the 43 farms.

The complexity of drystock farm systems and environmental conditions make it difficult to predict nutrient loss rates but the modelling showed there are some factors that appear to indicate risk, such as the proportion of a farm that is actively farmed (i.e. its effective area), and the proportions of different soil types. For nitrogen losses, the results pointed to the area in crop and the presence of dairy cattle as indicating risk.

Four mitigations were modelled, relating to nutrient inputs, cropping, stock, and fence pacing and wallowing. These mitigations appeared to be less effective for farms with lower nitrogen baseline losses than for farms with higher baseline nitrogen losses. Farms with low nutrient loss rates struggled to decrease them further. The effectiveness of the mitigations for farms with higher nitrogen losses was mixed. All of the large farms (farms with an effective area of more than 1,000 hectares) had nitrogen losses of 15 kg N/ha/year or less.

Drystock farms are largely low-input production systems that have adapted to support a given number of livestock. Those with limited inputs and without off-paddock structures had few mitigation options in OVERSEER. Those farms that used more inputs had relatively more options.

The mitigations' impacts on profitability were not related to a farm's baseline nutrient losses. The exception was the fence pacing and wallowing mitigation (discussed below).

Changing a farm's nutrient inputs (i.e. its fertiliser use) either reduced, or had no effect on, nitrogen loss, and achieved small reductions in phosphorus loss. This mitigation was not an option for some farms because in the 2013-14 year, 11 farms did not use any fertiliser and 16 farms used phosphorus but not nitrogen fertiliser. The mitigation increased profitability on many, but not all, farms – simply as a result of reduced fertiliser expenditure (the analysis covers one financial year). On average, profitability increased by 7% on the sheep and beef farms and by 14% on the deer farms. Longer-term reductions in fertiliser use most likely would result in lower farm productivity and profitability.

Changing a farm's crop policy was relatively effective (in comparison to the other mitigations modelled) for reducing nitrogen losses on most farms, but had a negative impact on profitability. The results appear to show a positive relationship between the proportion of effective area in crop on a farm and the reduction in nitrogen loss achieved through the cropping mitigation. For most farms, phosphorus losses did not appear to respond to this mitigation. The crop policy mitigation decreased profitability on average by 9% on the sheep and beef farms and by 0% on the deer farms (although there was some variability).

Reducing a farm's stock numbers by 10% had little effect on nutrient losses because all but one farm already had stocking rates of less than 15 SU/eff.ha. The average stocking rate for the 43 farms was 9.4 SU/eff.ha, with a median of 9.5. This mitigation resulted in relatively small reductions in nitrogen loss on most farms with little or no reductions in phosphorus loss, but it had a considerable impact on profitability. Average profitability decreased by 24% on the sheep and beef farms and by 33% on the deer farms. In drystock farming there is a strong relationship between stock numbers and profitability because, at least in terms of meat production, a farm's livestock are its product. As well, farmers spend little on imported feed so there were limited cost savings from lower stock numbers.

For deer farms, the fence pacing and wallowing mitigation was more effective in reducing phosphorus than the other mitigations modelled. Reductions in phosphorus loss ranged from 0% to around 15%. However, farm profitability decreased by an average of 27%. The effectiveness of this mitigation and its impact on profitability was directly related to the length of unfenced waterways on a farm.

The use of OVERSEER to model mitigation options may also overlook on-farm livestock management methods and does not reflect critical source areas for nutrient loss or events that cause mass earth movement (and associated phosphorus loss).

This section describes the research completed for the drystock case study farms. First it describes the specific methods used for the case study farm selection, including their distribution across Southland, and the modelling of these farms. It then outlines relevant characteristics of the case study farms before presenting the modelling results and outlining assumptions and limitations.

2.1. Case Study Farm Selection

In total, 46 drystock farms were chosen as case studies: 39 sheep and beef farms and seven deer farms. The initial target was 40 sheep and beef farms but one farmer had to withdraw for personal reasons. The sheep and beef farms and the deer farms were selected using two different selection methods, largely as a result of the different sample sizes involved for each industry.

The selection method for the 39 sheep and beef farms was to cover broad land use capability classifications (LUC) and rainfall categories within each of the Waiau, Aparima, Ōreti and Matāura FMUs. The broad LUC categories were: a category covering LUC classes 1-4 (land suitable for arable cropping) and a category covering LUC classes 5-7 (land not generally suitable for arable cropping). The broad rainfall categories were: a 'wet' category (average annual rainfall above 1,000mm) and a dry category (average annual rainfall below 1,000mm).

The process for selecting the sheep and beef farms was as follows:

Step 1: Farmers from the 41 farms in Southland included in B+LNZ's Sheep and Beef Farm Survey for 2013-14 were invited to participate and just over half accepted;

Step 2: Landcorp Farming Ltd. (a State Owned Enterprise) was approached and invited to participate, given its importance in Southland, and several Landcorp farms were included;

Step 3: Farmers from other farms were invited to represent the LUC and rainfall categories for the four FMUs and ensure a range of farm characteristics was captured. Most were former B+LNZ Sheep and Beef Farm Survey farms. A small number were either identified as being in localities where there were gaps, or the farmers volunteered at Environment Southland's public meetings for Water and Land 2020 & Beyond (a precursor to the People, Water and Land Programme).

The selection method for the seven deer farms was to cover a range of farm sizes and production systems from across Southland. The LUC and rainfall categories were not used for the deer farms because of the smaller sample size. In terms of the process, The Southland Branch of the New Zealand Deer Farmers Association sent a request for volunteers to its members.

2.1.1. Case Study Farm Distribution

For sheep and beef, the number of case study farms was distributed between the Waiau, Aparima, Ōreti and Matāura FMUs based on the proportion of the industry's land area in each FMU. For example, 52% of the sheep and beef industry's total area is in the Matāura and 15 of the 39 farms were located in this FMU; similarly, 20% of the industry's total area is in the Waiau and 9 farms are in this FMU. Overall, the 39 sheep and beef farms covered a total area of 47,000 hectares, which is roughly 6% of the industry's estimated total area (762,000 hectares) in Southland; the seven deer farms covered a total area of around 4,000 hectares, which is around 9% of the industry's estimated total area (43,000 hectares) in the region. Table C2 and Table C3 summarise the key categories used for the distribution of the sheep and beef case study farms.

Table C2: Distribution of 39 sheep and beef farms

FMU	Sheep and beef land in FMU (total ha)	FMU share of sheep and beef land in Southland	Number of case study farms	Case study area (total ha)	Case study share of sheep and beef land in FMU
Waiau	148,113	19%	9	14,000	9%
Aparima	68,616	9%	7	4,000	6%
Ōreti	152,756	20%	8	11,000	7%
Matāura	392,399	52%	15	18,000	5%
Total	**761,884**	**100%**	**39**	**47,000**	**–**

Source: Pearson and Couldrey (2016)

Table C3: Distribution of 39 sheep and beef case study farms

	LUC Classes 1-4		**LUC Classes 5-7**		**Total**
Annual Rainfall	**Under 1,000 mm**	**Over 1,000 mm**	**Under 1,000 mm**	**Over 1,000 mm**	
Waiau	0	5	0	4	**9**
Aparima	1	5	0	1	**7**
Ōreti	1	5	1	1	**8**
Matāura	5	5	2	3	**15**
Total	**7**	**20**	**3**	**9**	**39**

The LUC Class and rainfall categories were not used for the deer case study farms. However, of the seven deer farms, two farms were LUC Class 1-4 and five farms were LUC Class 5-7; two farms had rainfall under 1,000 mm (one LUC 1-4 and one LUC 5-7) and five farms had rainfall over 1,000 mm. For both the Waiau and the Matāura, one farm in each FMU had rainfall under 1,000 mm and one farm in each FMU had rainfall over 1,000mm. Overall, four of the seven farms were LUC 5-7 and had rainfall over 1,000mm.

The deer farms were deer focused, rather than more mixed drystock, with the deer enterprises forming at least two-thirds of the farm revenue for the seven deer case study farms. The case studies were either specialist deer farms (with no other livestock production) or farms that are predominantly deer (with deer comprising over 45% of the total stock units) with some sheep and/or cattle. Across these seven farms the production systems were more weighted towards velvet than venison.

When taken on their own, the case study deer farms do not fully reflect deer farming across the region because the majority of deer in Southland are located on mixed drystock farms. However, this targeted approach allowed modelling to focus on deer management rather than other drystock, which was well covered within the sheep and beef case study farms and included four mixed drystock farms (sheep, beef and deer). Altogether, there were 11 case study farms with deer enterprises.

Only one deer case study farm is large in terms of area at around 2,000 effective hectares, with the other six deer farms between 150 and 450 effective hectares. Large, extensive deer farms – particularly those in the Te Anau Basin, but also other hill and high country areas of the region – are not well covered within the seven case study deer farms. However, all four mixed drystock farms (with deer) had hill country and were over 1,000 total hectares.

2.1.2. Data Collection

Once the case study farms were selected, B+LNZ gathered and analysed the information for sheep and beef and for deer, with one qualified and experienced staff member visiting and interviewing all of the farmers. The information gathered was both quantitative and qualitative. In some cases, data was already available from B+LNZ Sheep and Beef Farm Survey records. This data provided a robust and standardised dataset. The farm visits were then used to gather additional information, specific to the input needs of the OVERSEER and FARMAX software. In other cases, all of the necessary data and information was collected during the farm visit, and sometimes clarified or verified subsequently.

During the farm visits, the B+LNZ staff member was often shown around the farm, which gave important context for the modelling of the farm data and the understanding of the results. The same staff member also undertook all of the modelling for these case study farms. As a result, a thorough contextual understanding of both sheep and beef farms and deer farms was gained, and this knowledge enhanced the modelling and analysis.

2.2. Case Study Farm Characteristics

Drystock farms (sheep/beef and deer) are diverse and complex businesses because their production systems involve a range of environmental factors and enterprise mixes. In Southland, few farms are on a single soil type or slope, or are limited to one stock class. Intensive finishing farms on the Southland plains tend to have the least diverse enterprise mix (principally sheep, which reflects farmers having adapted to their environment by running small light animals compared with cattle) although these often include arable cropping. This section presents some of the data collected from the 46 drystock farms to outline a number of key characteristics that were relevant to the modelling. These case studies are an indication of how drystock farming occurs within Southland – other drystock farms in the region will have features in common with one or more of these farms.

2.2.1. Size and Topography

A large range in both size and topography was covered across the 46 drystock case study farms. The sheep and beef farms ranged in area from around 100 hectares to well over 5,000 hectares, while deer farm areas ranged from around 200 hectares to over 2,000 hectares. Overall, 74% of the drystock farms had an effective area of less than 1,000 hectares. The remaining farms made up roughly 72% of both the total and effective areas covered by all of the case studies. Figure C1 shows the distribution of the 46 drystock farms by their effective areas - six case study farms have an effective area more than 2,000 hectares. Actual farm sizes are not presented to maintain farmer confidentiality. All other farm characteristics and results in this research are reported either as percentages or on a per hectare basis for the same reason.

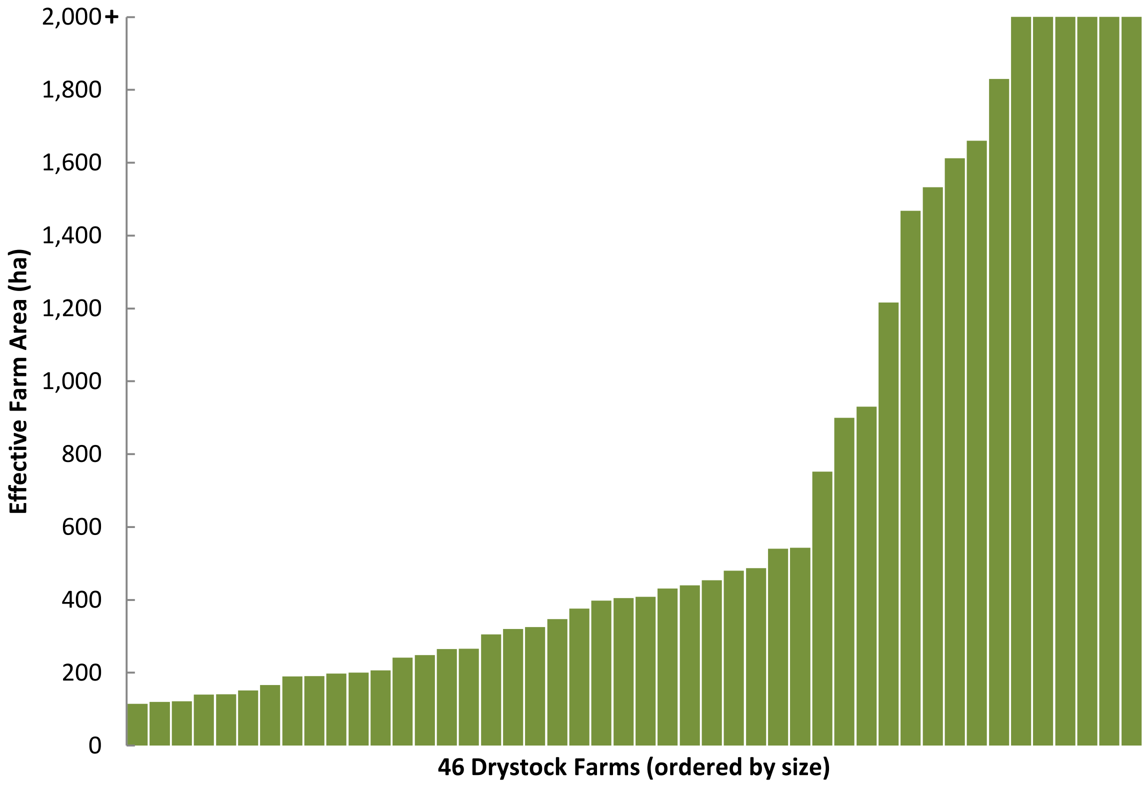

Figure C1: Distribution of effective areas for 46 drystock farms

The sheep and beef case study farms have proportions of flat (and rolling) land ranging from 0% to 100%, hill land ranging from 0% to 98% and steep land ranging from 0% to 75%[65]. The deer case study farms have proportions of flat land ranging from 0% to 93%, hill land ranging from 0% to 96% and steep land ranging from 3% to 32%.

Although some farms are either largely flat or largely hill, many have different proportions of two or all three slope classes and from the data there is no clear relationship between farm size and topography. For example, Farms 1 and 2 have similar total areas but Farm 1 is almost all flat land while Farm 2 covers a mix of flat, hill and steep land. Figure C2 shows the mix of topography on the 46 case study farms. Each farm has its own blend of topography, which influences other characteristics of the farm business. Topography is also a starting point for each farm's set of factors that contribute to its nutrient losses.

Farms 1 to 39 are sheep and beef farms and Farms 40 to 46 are deer farms. The farm numbers were randomly generated (i.e. they were not ordered by size or any other characteristic).

[65] The flat, hill and steep slope descriptions are based on the slope classes defined in the Overseer input standards: 'flat' is 0-7 degrees, 'rolling' is 8-16 degrees, 'easy hill' is 16-26 degrees, and 'steep hill' is greater than 26 degrees. In the context of this drystock research, 'flat' combined 'flat and rolling', 'hill' is easy hill, and 'steep' is steep hill.

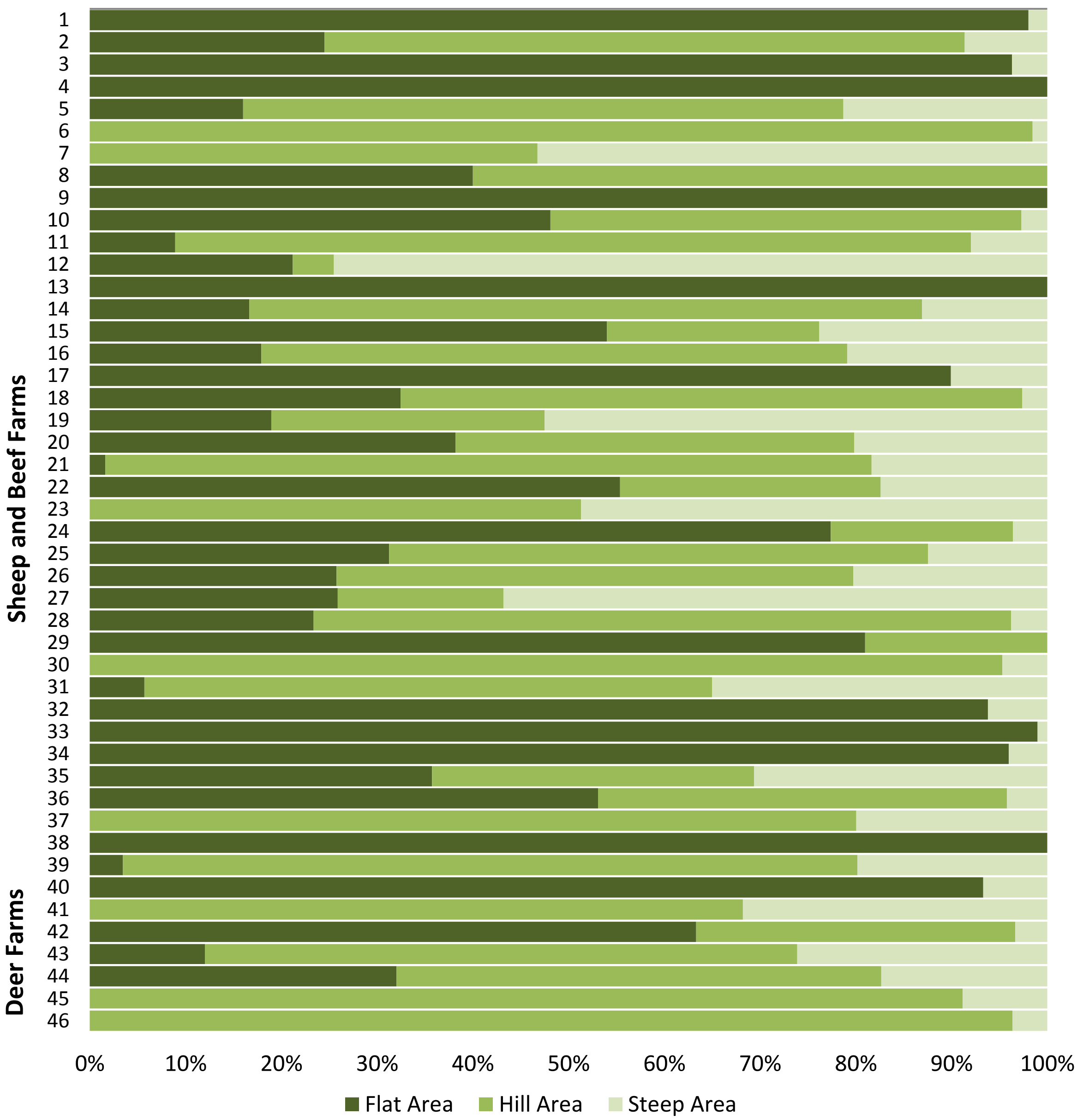

Figure C2: Slope mix for 46 drystock farms (total hectares)

2.2.2. Effective and Ineffective Areas

The case study farms also vary in the proportions of effective and ineffective areas. While the effective area of most farms is at least 80% of total area, some farms have large ineffective areas. The ineffective areas on many of the farms included wetlands (both natural and artificial), 'forestry' (includes farm forestry, native bush, hedges/windbreaks), infrastructure (races, buildings, houses) and other areas that are not grazed (duck ponds, lawns).

In some cases, non-productive areas were included in OVERSEER with the ineffective areas and, in other cases, non-productive areas were included with the effective areas and OVERSEER automatically estimated their extent. This difference occurred for a number of reasons, for example the sheer size of the farm or the available information. However, it is unknown what effect including non-productive areas with effective or ineffective areas had on the results. These non-pastoral areas were assessed separately as different blocks in OVERSEER, which estimates nutrient losses proportional to their impact.

In general, the sheep and beef farms have a higher proportion of ineffective area than the deer farms. Ineffective areas ranged from 0% to 55% of a farm's total area for the sheep and beef farms, and 2% to 29% of total area for the deer case study farms. The proportion of effective to ineffective area can be related to farm size and slope but it is not always the case. For example, the ineffective area on Farms 4, 7, 19 and 30 is between 30% and 55% of the total farm area. Farms 7 and 30 both include hill and steep land only, Farm 19 a mix of slopes, but Farm 4 is completely on flat land. All three farms vary considerably in size. The proportions of each farm's total area that are effective and ineffective are shown in Figure C3.

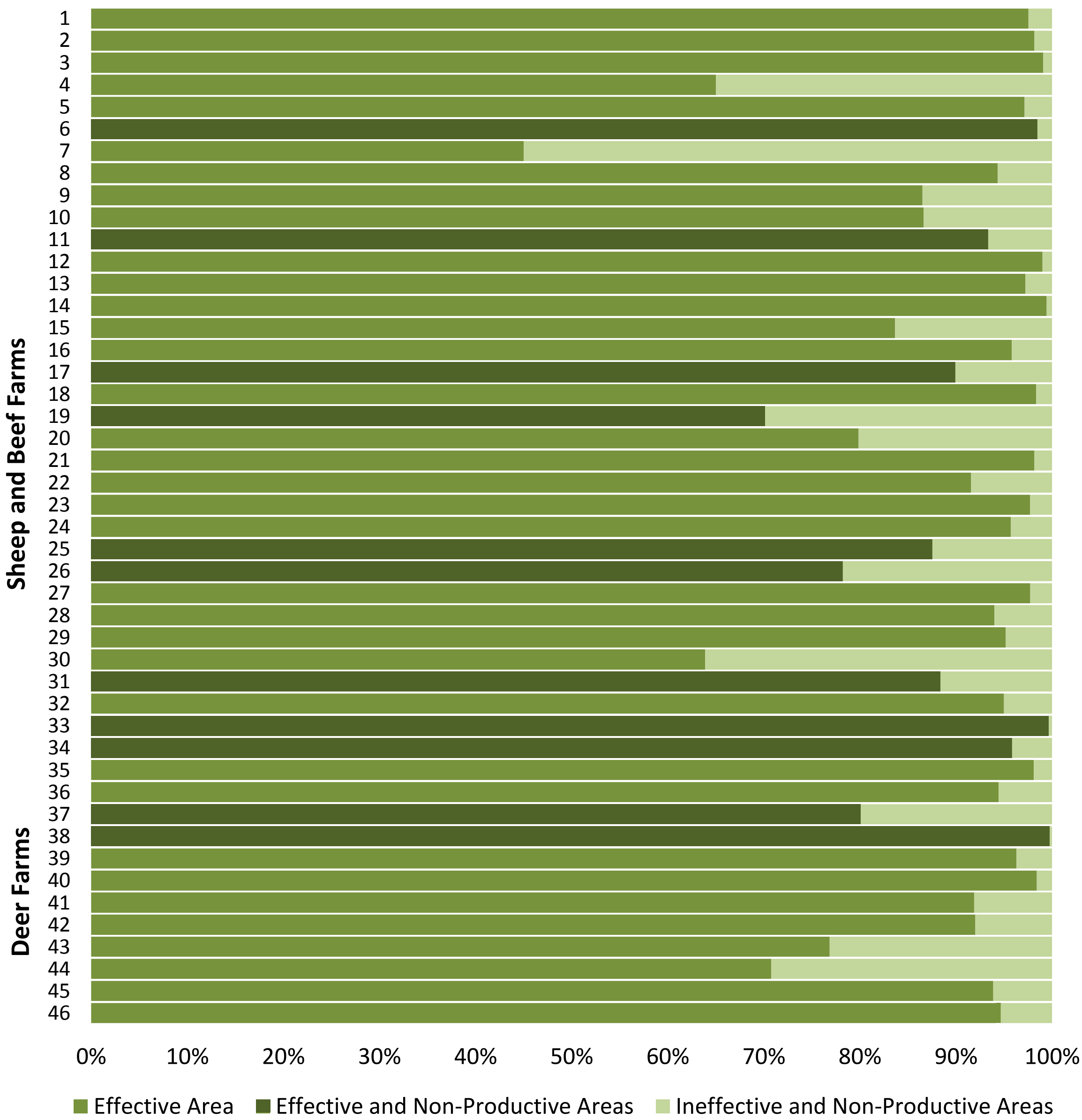

Figure C3: Proportion of effective and ineffective area for 46 drystock farms

2.2.3. Rainfall and Soil Drainage

Higher rainfall creates more opportunity for nutrient losses to leach through the soil or to be in run-off. How rainfall translates into nutrient losses is influenced by a farm's topography and the drainage abilities of a farm's different soil types. In Southland, these processes have the added complexity of artificial drainage in the form of mole/tile drains (including flexible plastic drainage pipe, such as Novaflo), which allow poorly drained soils to 'act' like well-drained soils (in terms of its aeration and moisture content) and are a preferential flowpath (refer to Section 2.2: Soils in Part A). OVERSEER includes information on the percentage of a farm block drained but the farmers did not necessarily have records about where drains were installed.

The drystock farms ranged from either completely poorly drained to completely well-drained. The poorly drained areas of the farms are those that are likely to be tile drained. The mix of well, imperfectly, and poorly drained soils on the farms are shown in Figure C4.

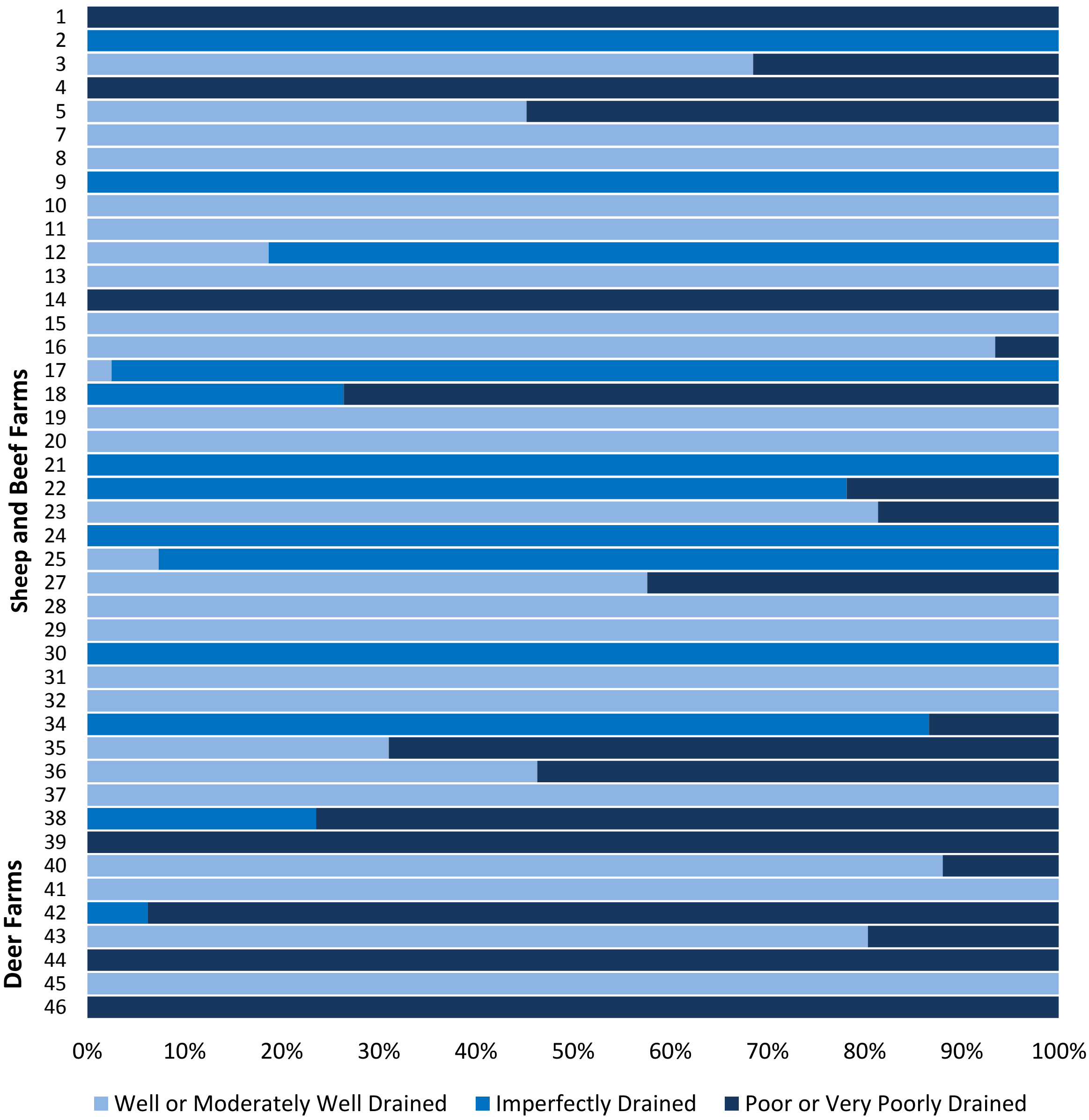

Figure C4: Proportion of effective area in different soil drainage classes for 46 drystock farms

2.2.4. Livestock Mix

In addition to differences in topography, effective and ineffective areas, the sheep and beef case study farms have a mix of livestock classes. Seven farms were sheep only and most farms had over 50% sheep stock units. Although sheep dominated, 11 farms had large beef enterprises (where beef cattle accounted for 30% or more of a farm's stock units). Four of the sheep and beef farms were mixed drystock farms (i.e. included a deer enterprise), and one of these farms had more deer stock units than its sheep and beef stock units combined, even though it was classified as a sheep and beef farm. Figure C5 shows each farm's livestock mix (measured in stock units) at 1 July, which is the industry standard date for physical statistics (e.g. Agricultural Production Statistics, Statistics New Zealand). The graph shows a wide range of stock mixes across the farms.

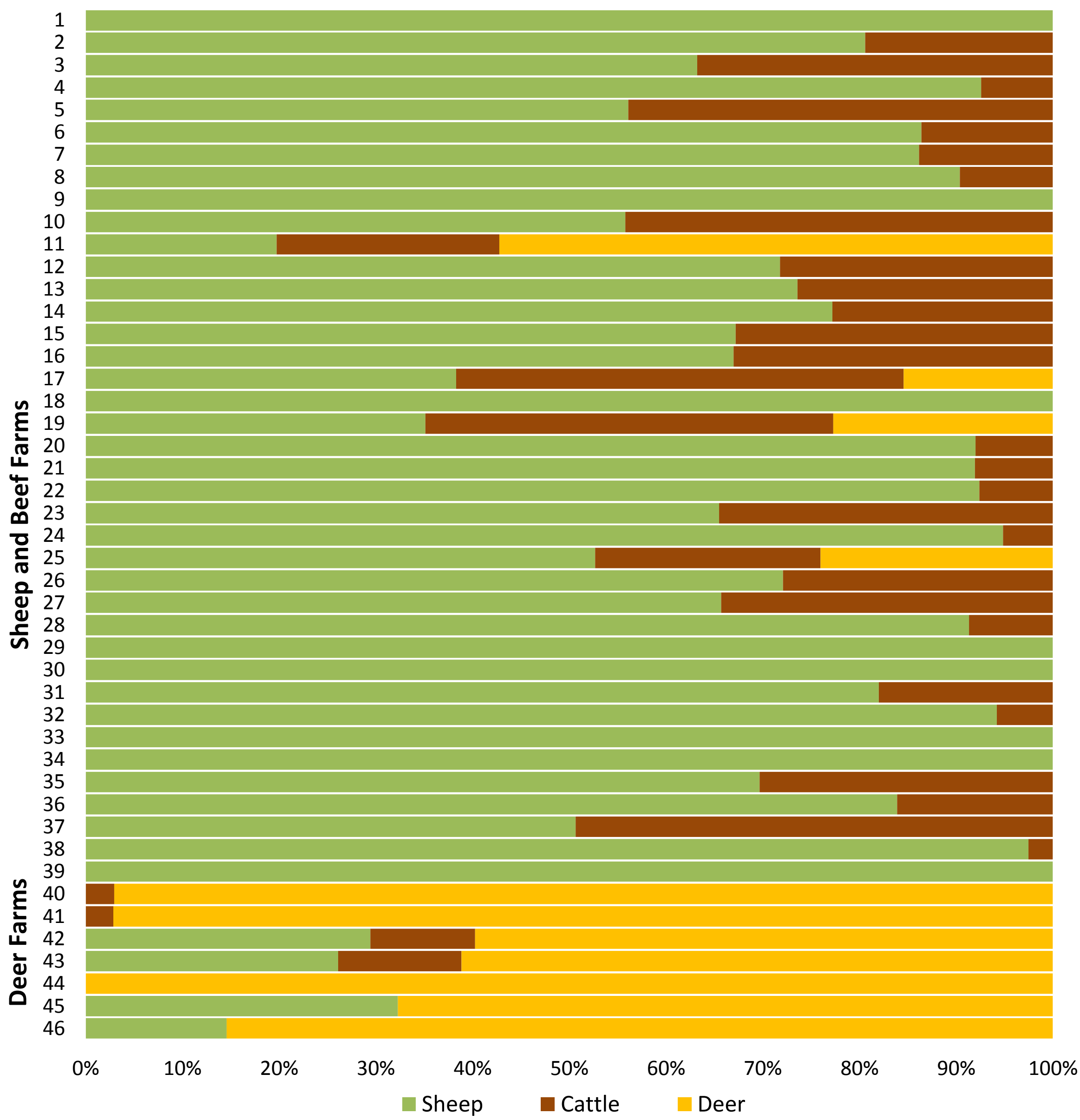

Figure C5: Proportional livestock mix for 46 drystock farms

In addition to sheep, beef cattle and deer, 15 of the 46 farms had dairy cattle at the start of the farming year (1 July 2013) and 14 of these farms were able to be modelled in OVERSEER (refer to Section 2.3). Over these 14 farms there were a total of 4,566 mixed age dairy cows, 1,621 rising one-year-olds and 457 rising two-year-olds. The final farm (Farm 33) had a large proportion of stock units as dairy cattle and couldn't be modelled due to the complexity of the farming operation.

Ten of the 15 farms with dairy cattle at the start of the farming year also gained revenue from dairy grazing while five farms did not (Figure C8). Two of the five farms with dairy cattle at the start of the farming year but no dairy grazing revenue also had a considerable proportion of effective area in crop (Figure C7), three farms had crop areas of 100 hectares or more, and one farm had both.

All seven deer farms were predominantly deer (over 50% deer stock units) because the case study farms were selected on this basis. Six of these farms also had sheep and/or beef enterprises: two farms included both sheep and beef cattle, two included just sheep, two included just beef cattle. Farm 44 was exclusively deer. Deer farms produce two main products; venison (mostly from one or two-year-old animals) and velvet (mostly from older stags). Figure C6 shows percentage of deer stock class numbers (based on DINZ stock unit conversions) within the deer enterprise within the seven deer farms. It also shows the percentage of sheep and beef stock units on these farms.

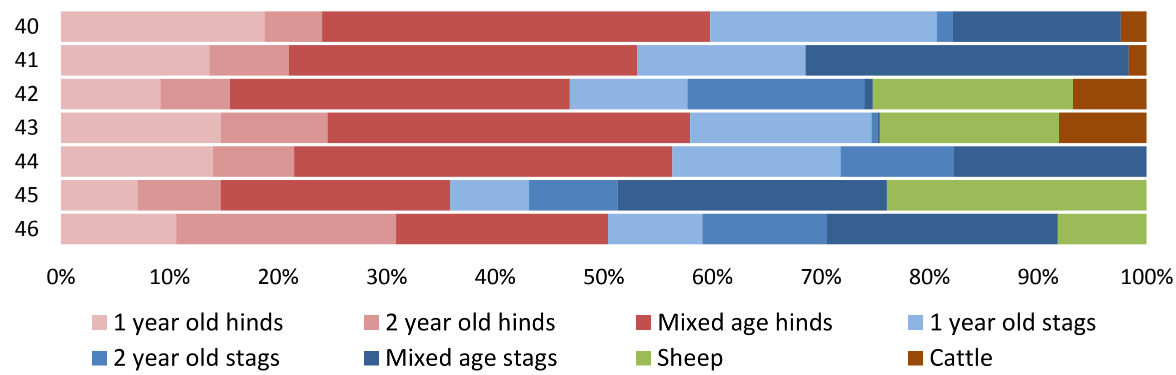

Figure C6: Proportional deer stock mix for seven deer farms

2.2.5. Cropping

Almost all of the case studies used part of the farm to grow feed crops for carrying their capital livestock over winter. The crops planted on the farms included: swedes, rape, kale, turnips, barley, wheat, oats, lucerne, fodder beet, triticale, whole crop barley, and whole crop barley silage. Overall, the proportion of a farm's effective area in crop ranged from none to almost 46%. The average proportion of effective area in crop was 8% and 40 farms had 11% or less of effective area in crop, including Farm 9, which had no area in crop. The remaining six farms had considerably more effective area in crop (17 to 46%). It is unknown if the level of cropping area was maintained on an on-going basis. The range in crop areas was from none to more than 500 hectares and the average crop area was 78 hectares. However, over 80% of the farms had 80 hectares or less in crop and the median crop area was 32 hectares. Figure C7 shows each farm's proportion of effective area in crop in 2013-14. The three grey bars are the three farms (Farms 6, 26, and 33) that were unable to be modelled in OVERSEER (refer to Section 2.3). Two of these farms have relatively large proportions (i.e. over 20%) of effective area in crop but the third (Farm 26) has a small proportion of its effective area in crop.

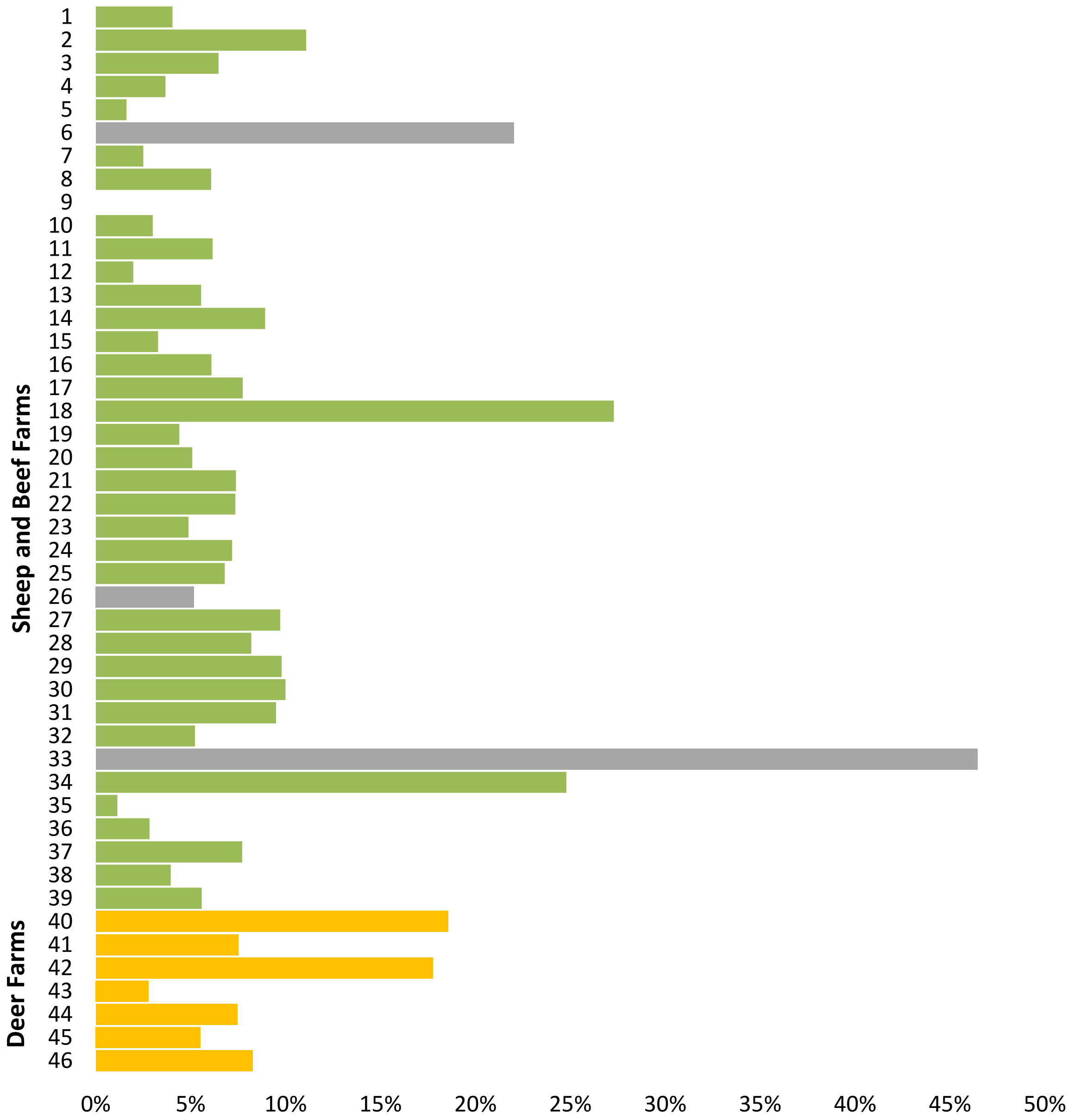

Figure C7: Proportion of effective area in crop for 46 drystock farms

2.2.6. Revenue Streams

It is conventional in the drystock industry to measure in stock units a farm's capital livestock base at the start of the season, but this mix can change at different times of the year, as is highlighted by the revenue received (over the farming year) (Table C4). The case study farms have a variety of revenue streams, in comparison to other industries. In some cases, these revenue streams do not line up with the stock units on hand at the start of the farming year, simply reflecting the dynamic and changeable physical and financial environment characteristic of drystock farming. As a simple example, at the start of the season Farm 18 was 100% sheep, but generated 30% of its revenue from cattle and 34% from dairy grazing over the financial year. Beef cattle may have been bought in to finish and sell or, alternatively, another farm's beef cattle could have been grazed for a period during the year. In both scenarios, revenue would be created from beef cattle that were not on farm at balance date.

Table C4: Revenue streams for 43 drystock farms[66]

Farm Type	Average gross revenue ($/eff.ha)	Median gross revenue ($/eff.ha)
Sheep	$845	$773
Wool	$128	$125
Beef Cattle	$160	$98
Deer	$1,039	$1,013

In addition to more traditional revenue streams, 12 farms (11 sheep and beef and 1 deer) also earned revenue from dairy grazing: one of these farms had a considerable proportion of effective area in crop and another farm had over 50 hectares in crop. Average gross revenue earned was $302 per effective hectare and median gross revenue was $281 per effective hectare. In total, 17 out of 46 farms (37%) either earned revenue from dairy grazing and/or had dairy cows at the start of the farming year (two farms earned revenue from dairy grazing but did not have dairy cattle at the start of the farming year). Only one farm earned revenue from a single source (deer). Figure C8 shows the revenue mix from different livestock classes for the case study farms.

The three case study farms unable to be modelled in OVERSEER (Farms 6, 26 and 33) were not included because, once the nutrient loss information was unobtainable, the financial analysis was not undertaken.

66 Only 43 of the 46 farms were able to be modelled in OVERSEER.

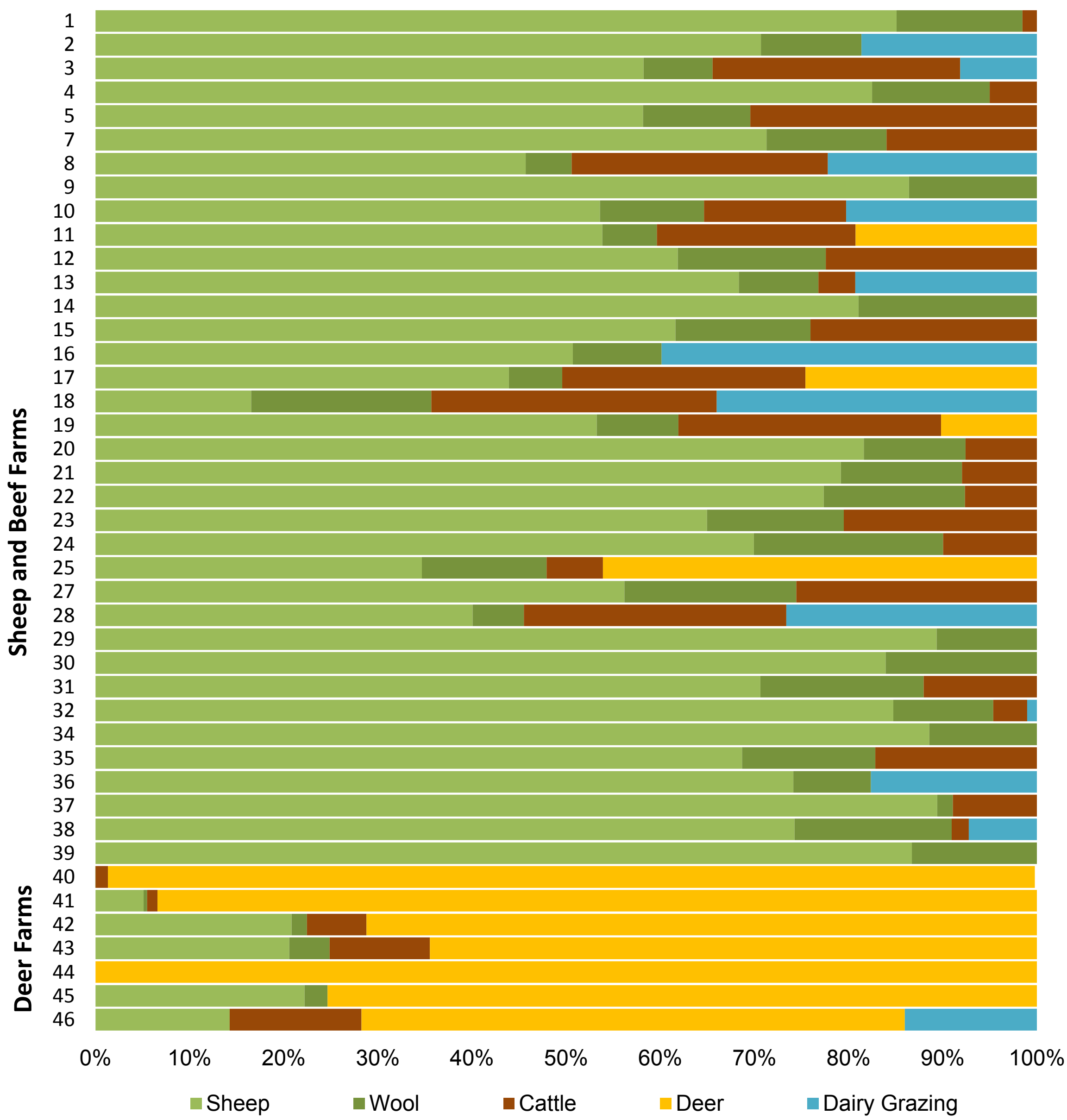

Figure C8: Proportional mix of revenue streams for 43 drystock farms ($/effective hectare)

2.3. Baseline Modelling

The data and information was used to model each of the case study farms in OVERSEER and FARMAX. The aim of this modelling was to estimate the farms' existing performance in terms of profitability and nutrient losses and possible performance with further mitigations to manage their nutrient losses.

First, a pair of base files was produced for each farm using OVERSEER (version 6.2.0) and FARMAX (version 6.5.5). Second, copies of these base files were then used to model mitigations designed to reduce a farm's nutrient losses. A key step in the modelling was to assign the different parts of the farm into management 'blocks' in OVERSEER (i.e. cropping, slope, stock, or fertiliser regime), in accordance with the OVERSEER Best Practice Data Input Standards (OVERSEER Ltd., 2015). In general, farms with greater complexity required more blocks in OVERSEER to accurately portray a farm. For the 43 case study farms modelled, between 5 and 18 blocks were needed to accurately determine the farm's nutrient budget.

Of the 39 sheep and beef farms, 36 were able to be modelled successfully in OVERSEER but for 3 farms a base file could not be modelled without making significant changes to the farm operations. The farms were different in their environmental conditions, stock enterprises and yield, and crops grown. However, they were all relatively complex production systems. Information on the physical characteristics of the three farms (Farms 6, 26 and 33) is included in Section 2.2 but the financial and nutrient loss characteristics are not because this information was not successfully modelled in FARMAX or OVERSEER due to the complexities of the farming operation.

When modelled in OVERSEER, all three farms produced the same error message – "excess feeding to a stock class in a month". This 'bug' is well-known to OVERSEER users, and there are standard 'fixes' that can be applied to the farm file to produce a nutrient budget. One fix is to reduce crop yield but in this case it did not resolve the issue and, in trying to respond to the error message, the modelled farms increasingly did not accurately represent the actual farms. Other 'fixes' can be to artificially change the stocking rate or area of crop planted; they were not used because a similar situation would have occurred. It was accepted that these farms could not be modelled in OVERSEER Version 6.2.0, without significant manipulation of the base file.

The OVERSEER owners and developers are constantly working to improve the model, and these farms may be accommodated in later versions released. However, this result indicates that the ability to accurately represent some drystock farms in OVERSEER is an important consideration for its use in policy.

All seven deer farms were able to be modelled in OVERSEER. However, it can be relatively imprecise when trying to express the complexities of the deer farm system. For example, fence pacing and wallowing is inputted into OVERSEER using a simple check box. That is, fence pacing and wallowing either occurred or did not occur on a farm; and the extent of this behaviour on a farm was not able to be expressed.

2.4. Baseline Results

This section presents the baseline nutrient loss results profitability results for the 43 drystock farms (36 sheep and beef farms and seven deer farms) that were modelled. The results provide the starting point for the mitigation modelling in the following sections. Unless stated otherwise, all the nutrient loss and profitability results are per hectare. Nutrient losses are reported using each farm's total area (i.e farm nutrient losses are divided by its total area to give a per hectare rate) and profitability results are reported using each farm's effective area (i.e. farm profitability is divided by its effective area to give a per hectare rate).

2.4.1. Nitrogen

Overall, two-thirds of drystock farms had nitrogen losses of less than 20 kg N/ha/year. However, the range in baseline nitrogen losses varied between the sheep and beef farms and the deer farms. Sheep and beef farms had baseline nitrogen losses from 5 to 37 kg N/ha/year, with two-thirds less than 15 kg N/ha/year and one-third more than 15 kg N/ha/year; The deer farms had a range of baseline nitrogen losses from 9 to 50 kg N/ha/year; and The mixed drystock farms (from the 36 sheep and beef farms that had deer) all had losses from 10 to 15 kg N/ha/year. Possible factors driving these results are discussed later in this section. Table C5 gives average and median baseline nitrogen loss results for the 43 modelled drystock farms. Figure C9 shows the baseline nitrogen losses for those farms.

Table C5: Baseline nitrogen results for 43 drystock farms

Case Study Farms	Average Nitrogen Loss (kg N/ha/year)	Median Nitrogen Loss (kg N/ha/year)
43 Drystock farms	18	13
36 Sheep and beef farms	15	12
7 Deer farms (with 4 sheep and beef farms with deer)	23	17
7 Deer farms (without 4 sheep and beef farms with deer)	30	34

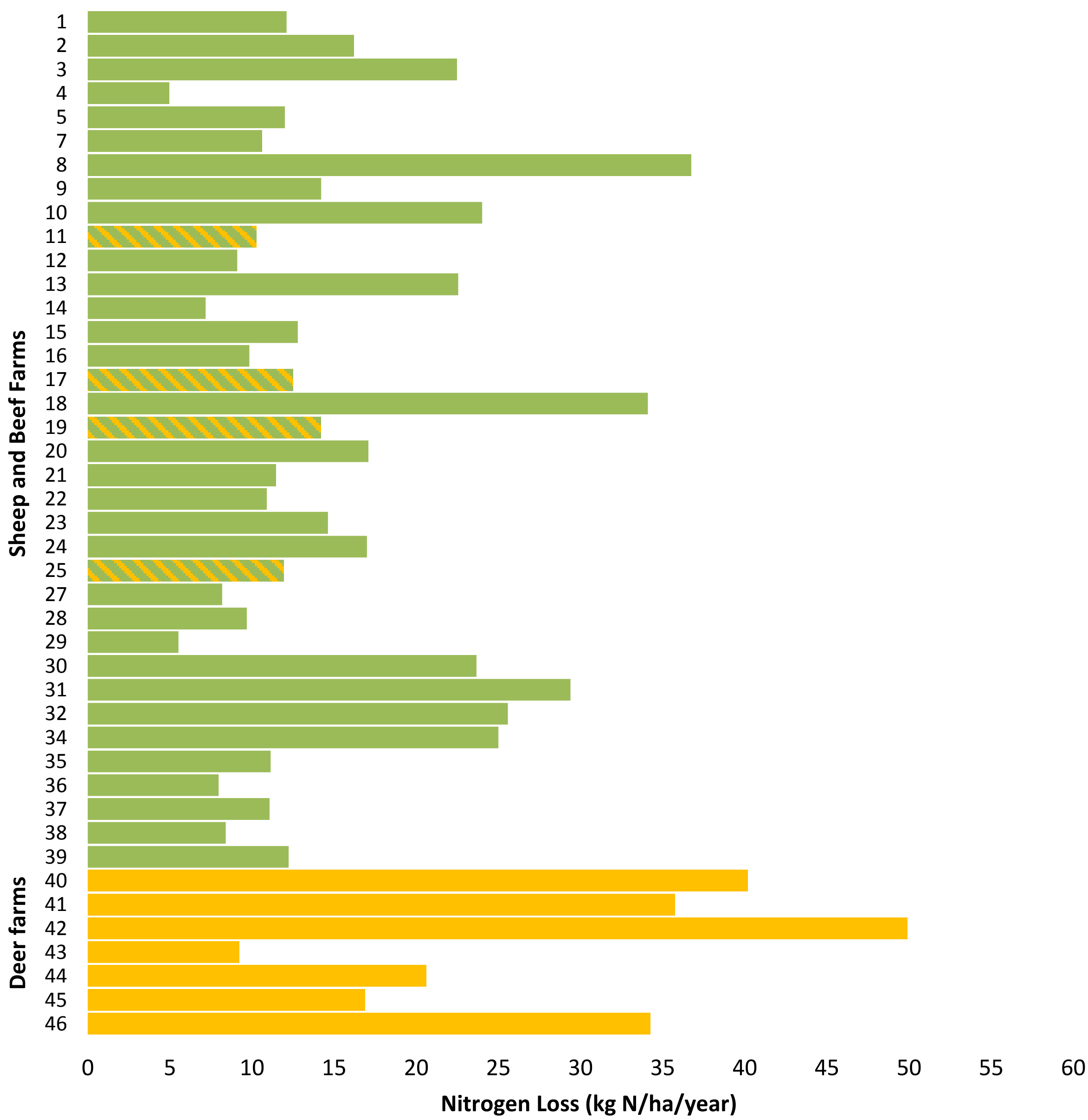

Figure C9: Baseline nitrogen loss for 43 drystock farms
Note: green bars = sheep and beef farms, yellow bars = deer farms, yellow with green hash = sheep, beef and deer farms

Figure C10 shows the distribution of baseline nitrogen losses for the 36 sheep and beef farms.

For deer, six of the seven deer farms had nitrogen losses above 15 kg N/ha/year. Based on similar research in Canterbury, it is not unexpected that the deer farms tend to have higher nitrogen losses than sheep and beef farms. Two of the deer farms had nitrogen losses above the highest sheep and beef farm (37 kg N/ha/year) with 40 and 50 kg N/ha/year. Both of these farms had relatively high proportions of the effective areas in crop compared to the other deer farms. Neither deer farm earned dairy grazing revenue nor had dairy cows.

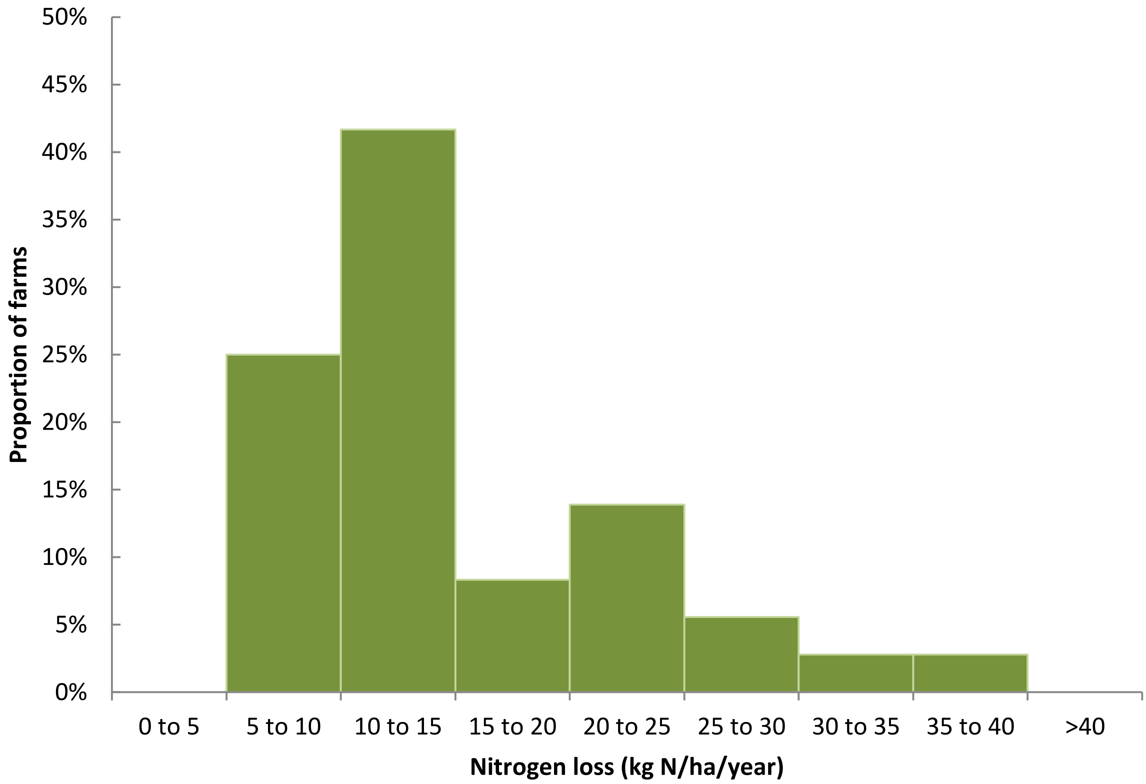

Figure C10: Distribution of nitrogen loss for 36 sheep and beef farms

2.4.2. Phosphorus

Similar to the nitrogen losses, the range in baseline phosphorus losses varied between the sheep and beef farms and the deer farms, with higher phosphorus loss on some deer farms. For the 36 sheep and beef farms the range in phosphorus loss was less than 0.3 to 1.4 kg P/ha/year. The seven deer farms had a range in phosphorus loss between 0.5 and 2.5 kg P/ha/year, with one farm almost 0.8 kg higher than any of the other deer farms. The four mixed drystock farms (sheep and beef case study farms with deer) had losses between 0.6 and 1.4 kg P/ha/year. Table C6 gives average and median baseline phosphorus loss results for the 43 drystock farms. Figure C11 shows the baseline phosphorus losses for those farms.

Table C6: Baseline phosphorus results for 43 drystock farms

Case Study Farms	Average Phosphorus Loss (kg P/ha/year)	Median Phosphorus loss (kg P/ha/year)
43 Drystock	0.9	0.7
36 Sheep and beef	0.7	0.6
7 Deer + 4 sheep and beef farms with deer (mixed drystock)	1.2	1.4
7 Deer	1.5	1.4

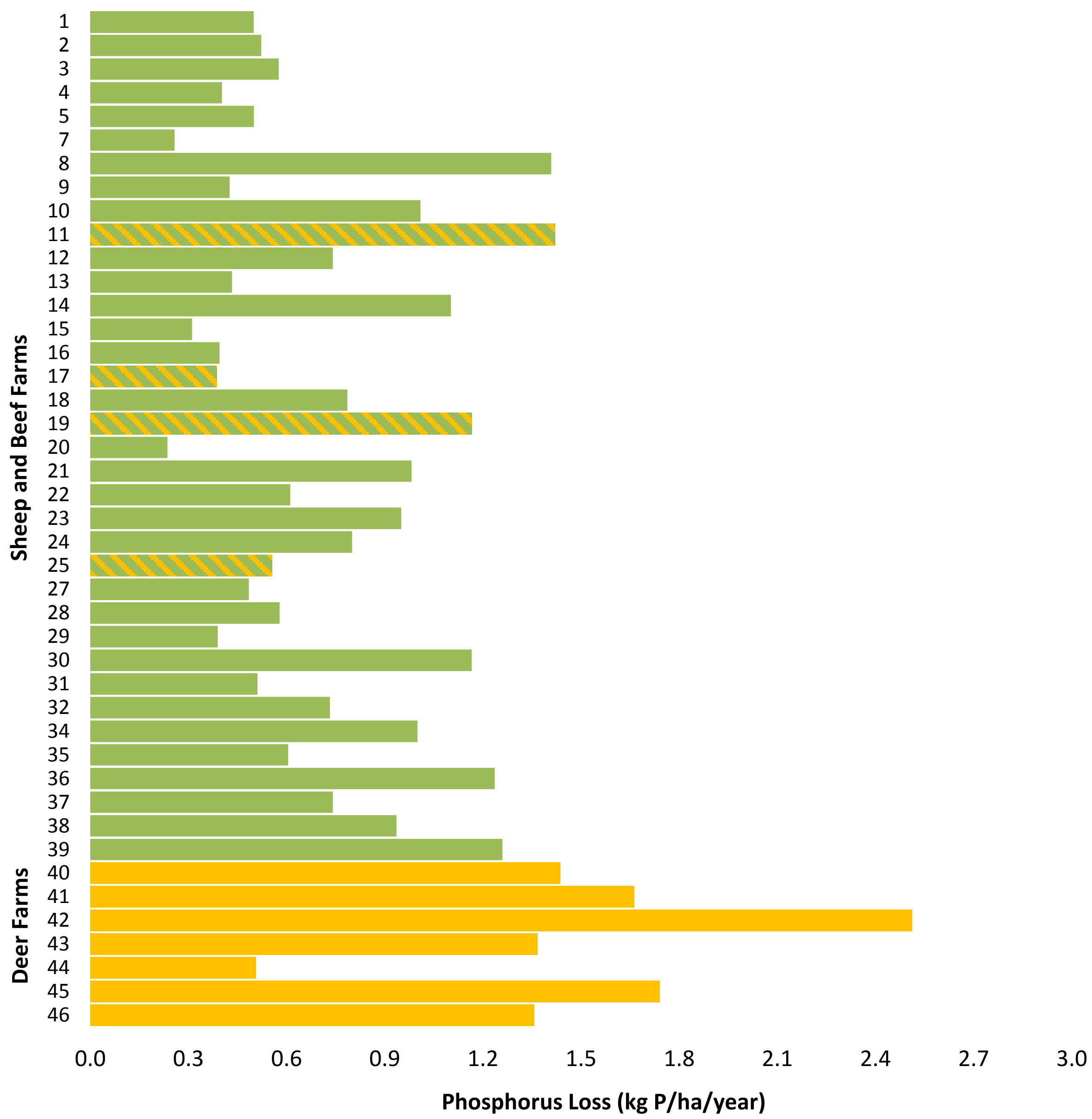

Figure C11: Baseline phosphorus loss for 43 drystock farms
Note: green bars = sheep and beef farms, yellow bars = deer farms, yellow with green hash = sheep, beef and deer farms

In general, the seven deer farms had higher losses than the sheep and beef farms. This result is not unexpected because natural deer behaviours, such as wallowing and fence pacing, are sources of phosphorus loss. While there is little in the way of comparable information for nitrogen or phosphorus loss rates for deer farms in New Zealand, a similar study in Canterbury had narrower ranges for both nutrients (8 – 29 kg N/ha/year and 0.1 – 1.2 kg P/ha/year). Many factors could contribute to differences in loss rates between regions such as rainfall, temperature (the length of winter), soil types and different farming practices (e.g. the extent of cropping/winter grazing).

Phosphorus losses for the sheep and beef farms were more evenly distributed than the nitrogen losses. Around 80% of the farms had phosphorus losses of 1 kg P/ha/year or less, and 90% of farms had losses between 0.3 and 1.3 kg P/ha/year. Figure C12 shows the distribution of baseline phosphorus losses for the 36 sheep and beef farms.

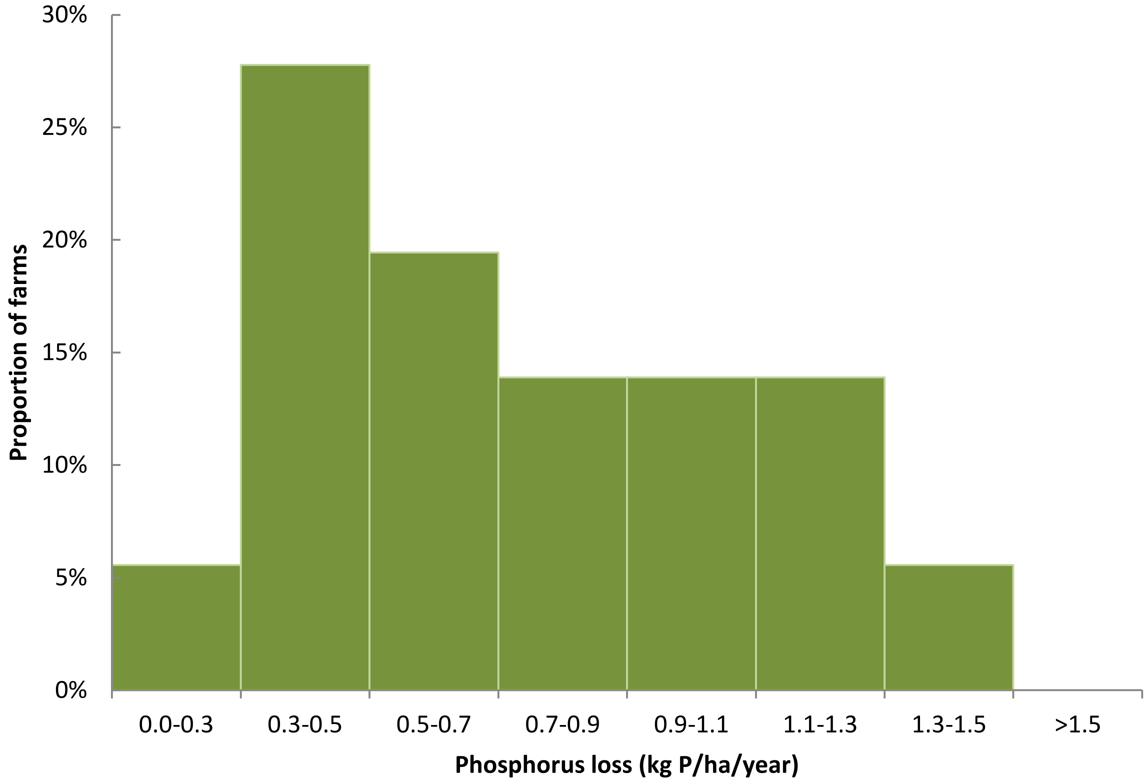

Figure C12: Distribution of phosphorus loss for 36 sheep and beef farms

The sheep and beef farm with the highest phosphorus loss (Farm 11) is a medium to large farm with a relatively high proportion of effective area. The farm has a large area of well-drained hill country and small areas of moderately well-drained flat and steep land. The farm has a stocking rate of around 8 SU/eff.ha and a relatively low proportion of effective area in crop. The majority (57%) of the stock units on the property are deer.

The highest phosphorus loss of all the case study farms (Farm 42) is the deer farm that also had the highest nitrogen loss out of all the case study farms.

The farm with the lowest phosphorus loss of all the drystock farms (Farm 20) was a small farm with a relatively high proportion of effective area. The farm is all moderately well-drained and fairly evenly spread across flat, hill and steep land. The farm has a stocking rate of around 12 SU/eff.ha and a relatively low proportion of effective area in crop (swedes).

There was some variation in both nitrogen and phosphorus losses between FMUs for the 36 sheep and beef farms modelled (Table C7). It is likely that this is the result of environmental differences across the region. This may be a reflection of the way in which farmers meet the complexities of farming in the different evironments across the FMUs. Each farmer will meet the challenges in a different way, even neighbours could farm very differently based on the outcome that they are seeking.

Table C7: Nutrient losses for 36 sheep and beef farms by FMU

FMU	Nitrogen loss (kg N/ha/year)		Phosphorus loss (kg P/ha/year)	
	Average	Median	Average	Median
Waiau	17	13	0.8	0.7
Aparima	14	10	0.6	0.6
Ōreti	20	16	0.6	0.5
Matāura	12	11	0.6	0.5

2.4.3. Profitability

Profitability varied greatly across the case study farms. It was not necessarily linked to one specific farm type or characteristic because farmers try to optimise a complex mix of factors. The results are a snapshot of the profitability of the case study farms in the 2013-14 financial year, and may not necessarily reflect a longer-term average for the farm.

Farm 'profitability' can be measured in a number of different ways. Two standard measures used in the drystock industries are Earnings before Interest, Tax and Rent (EBITR) and Farm Profit before Tax (FPBT). EBITR provides a measure that is more comparable across farms than FPBT because it puts each farm on a freehold[67], unencumbered[68], lease-free[69] basis by removing the effect of interest and rent, which are costs of capital (generally land) incurred by the business. While the distribution and variability between farms for EBITR is similar to that for FPBT, it is more consistent measure for comparison. Like EBITR, FPBT takes into account the expenditure of the business but variation in debt/equity levels can distort the perception of relative performance of different farms.

This research uses the farm prices and costs from 2013-14. A single year was used because of the complexity involved with multiple enterprises. In 2013-14, on average around 70% of gross revenue on Farm Class 7 Intensive Finishing farms, which is the most populous category of farms in Southland, was from sheep sales, with a further 13% from wool, 3% from beef cattle, 5% from dairy grazing, and the remainder from a mix of enterprises. From 1990-91 to 2016-17, inflation-adjusted lamb prices have increased steadily (by a compound rate of 2.6% each year) at about the same rate as the farm-gate milk price. Lamb prices have been generally less variable than milk prices.

Figure C13 shows the profitability (as measured by EBITR per effective hectare) of the case study farms that could be modelled in OVERSEER. Table C8 gives more specific results for each industry. There are outliers that have markedly smaller or larger profitability than the average or median values.

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[67] As if it owned the land.
[68] Debt free.
[69] As if it owned the land rather than renting some or all of it.

Table C8: Average and median profitability values for 43 drystock farms ($/eff.ha)

Farm Type	Earnings Before Interest, Tax and Rent (EBITR)		Farm Profit Before Tax (FPBT)	
	Average	Median	Average	Median
Sheep and Beef	$599	$485	$472	$338
Deer	$476	$395	$156	$163

Unless otherwise stated, all financial measures are EBITR per effective hectare because it is this land that is actively farmed and drives profit.

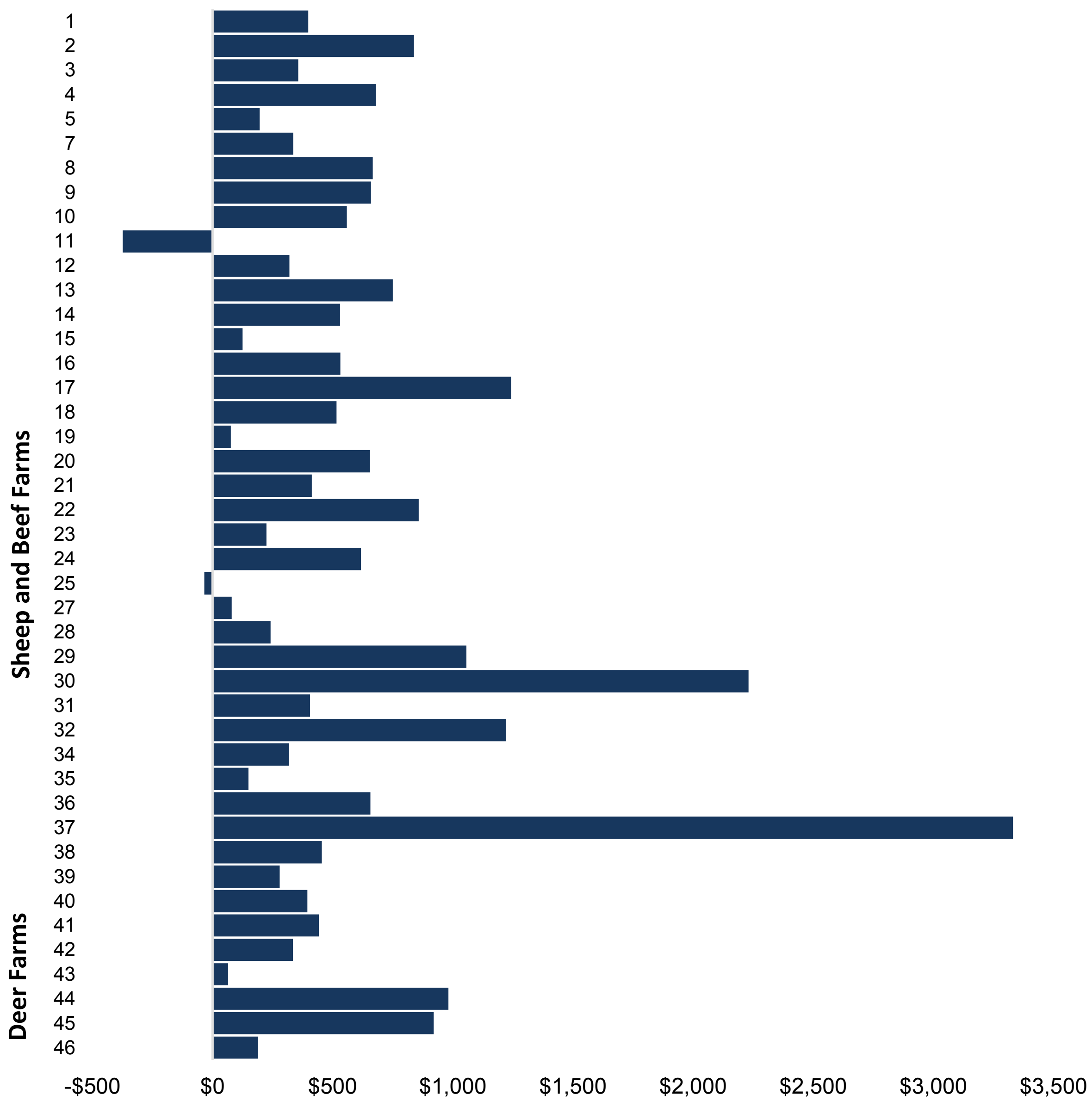

Figure C13: Profitability (EBITR) of 43 drystock farms ($/eff.ha)

There was some variation between FMUs (Table C9). Overall, the farms from Waiau, Matāura, and Aparima were larger than farms from Aparima and Ōreti. The Waiau and Matāura farms were also more profitable than farms from Aparima and Ōreti, where profitability was similar. Farms in Aparima and Matāura FMUs had a higher proportion of effective area compared to the farms in the Ōreti and Waiau. Most farms across the FMUs have similar proportions of effective area in crop but some farms in Matāura had larger proportions of crop. Average case study farm characteristics are not reported by FMU because of farmer confidentiality.

Table C9: Median characteristics of 36 sheep and beef farms by FMU

FMU	Total area (ha)	Proportion of effective area	Proportion of effective area in crop	Profitability (EBITR $/eff.ha)
Waiau	550	90%	6%	$560
Aparima	490	97%	5%	$405
Ōreti	280	87%	6%	$400
Matāura	500	95%	7%	$530

The seven deer case study farms were selected across the region. These farms had an average total area of 545 hectares but a median area of 260 hectares. The proportion of effective to ineffective area was an average of 88% and median of 92%. The proportion of effective area in crop was an average of 10% and a median of 7%. Profitability for these farms was an average of $476 per effective hectare and a median of $395 per effective hectare.

2.4.4. Nutrient Loss and Profitability

This section outlines analysis of nutrient loss and profitability for the 43 drystock farms modelled to explore the baseline results. The section also briefly discusses the farm characteristics in light of these results and in advance of the mitigation modelling in the next section.

Nitrogen

For the 43 drystock farms modelled, median profitability was $442 per effective hectare and average profitability was $579 per effective hectare. Average profitability was considerably higher than the median because of two large outliers in the data. In general, a tight group of 13 farms had relatively low nitrogen losses and relatively low profitability and the remaining farms were more evenly spread between nitrogen loss and profitability.

Using the medians for nitrogen loss (13 kg N/ha/year) and profitability ($442 per effective hectare) to group the farms, 9 drystock farms had relatively higher profitability and lower nitrogen loss and, conversely, another 9 drystock farms had relatively low profitability and higher nitrogen loss. Table C10 gives the distribution of farms for nitrogen loss and profitability. Figure C14 shows nitrogen loss and profitability for the 43 drystock case study farms modelled.

Table C10: Profitability (EBITR) and nitrogen loss for 43 drystock farms

	Less than or equal to 13kg N/ha/year	More than 13kg N/ha/year
More than $442 / eff.ha	9 farms (21%)	12 farms (28%)
Less than $442 / eff.ha	13 farms (30%)	9 farms (21%)

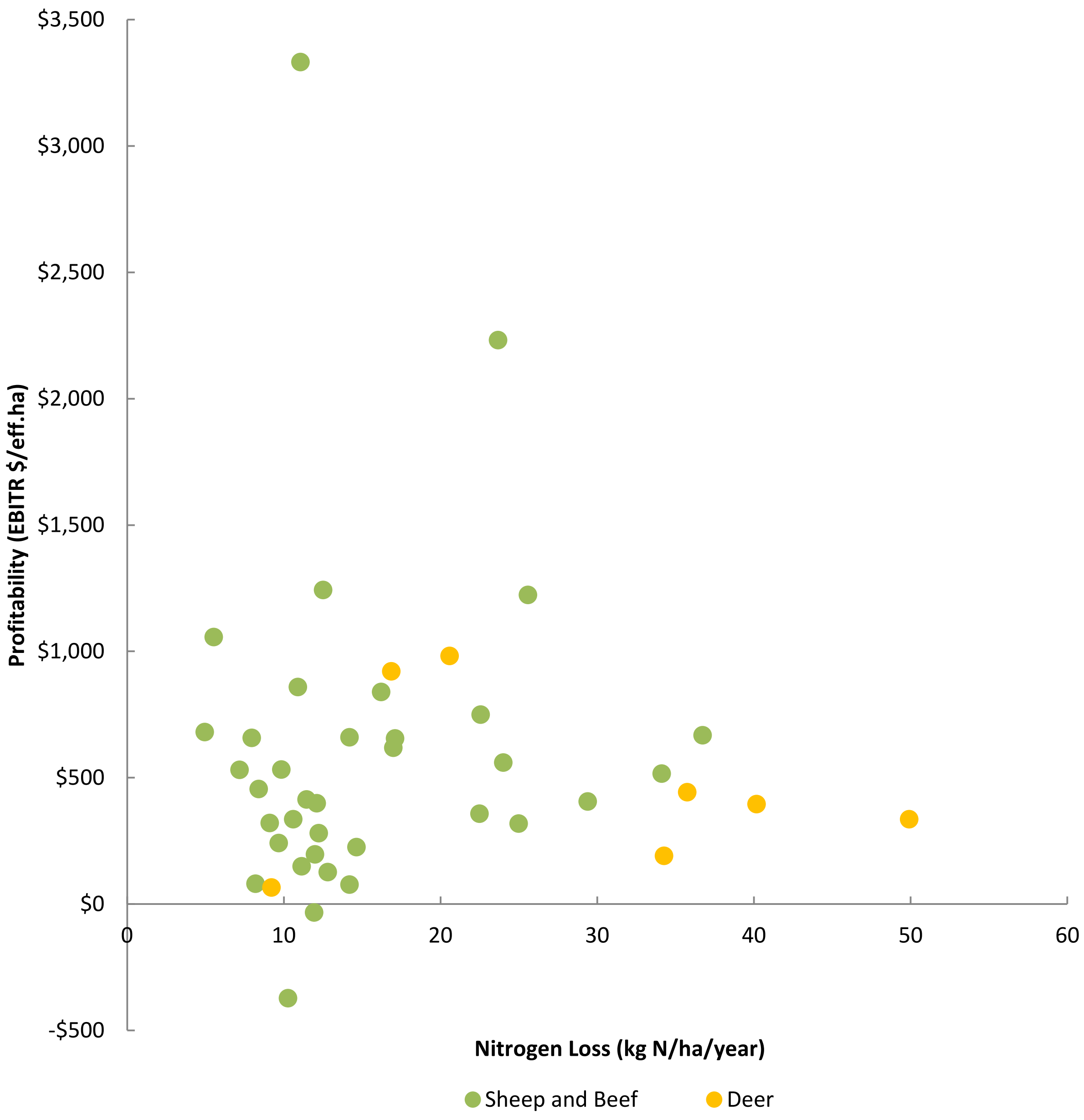

Figure C14: Baseline nitrogen loss for 43 drystock farms

Phosphorus

There is a narrower spread of phosphorus loss than for nitrogen loss. Using the drystock farm medians for phosphorus loss (0.7 kg P/ha/year) and profitability ($442 /eff.ha) to group the farms, 11 farms had higher phosphorus losser and lower profitability. Seven of these farms also had higher nitrogen losses. 12 farms had relatively lower phosphorus loss and higher profitability. Five of these farms also had lower nitrogen losses.

Table C11 gives the number of farms above and below the medians for phosphorus loss and profitability. Figure C15 shows profitability and phosphorus loss for the 43 drystock case study farms modelled.

Table C11: Profitability (EBITR) and phosphorus loss for 43 drystock farms

	Less than or equal to 0.7 kg P/ha/year	More than 0.7 kg P/ha/year
More than $442 / eff.ha	12 farms (28%)	9 farms (21%)
Less than $442 / eff.ha	11 farms (26%)	11 farms (26%)

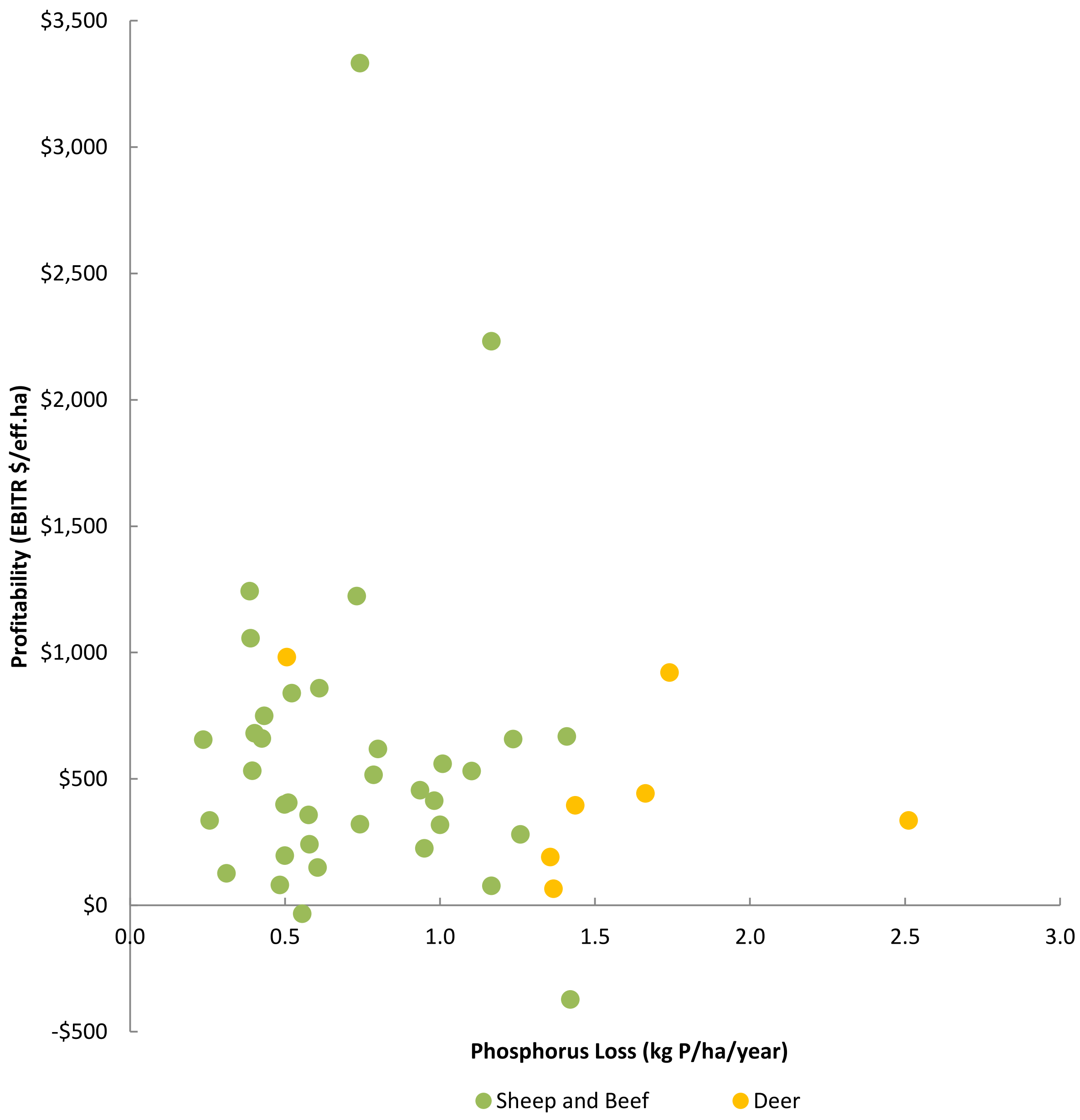

Figure C15: Baseline phosphorus loss for 43 drystock farms

Some of the drivers of nitrogen and phosphorus losses are similar (e.g. rainfall), even though the pathways (e.g. deep drainage or overland flow) are often different. However, any relationship between nitrogen and phosphorus losses for the 43 drystock farms modelled was unclear – in some cases, farms had either higher or lower losses of both nitrogen and phosphorus, but in other cases, farms had relatively high losses of one or other of the two nutrients.

Figure C16 shows the relationship between nitrogen loss and phosphorus loss for the 43 case study farms.

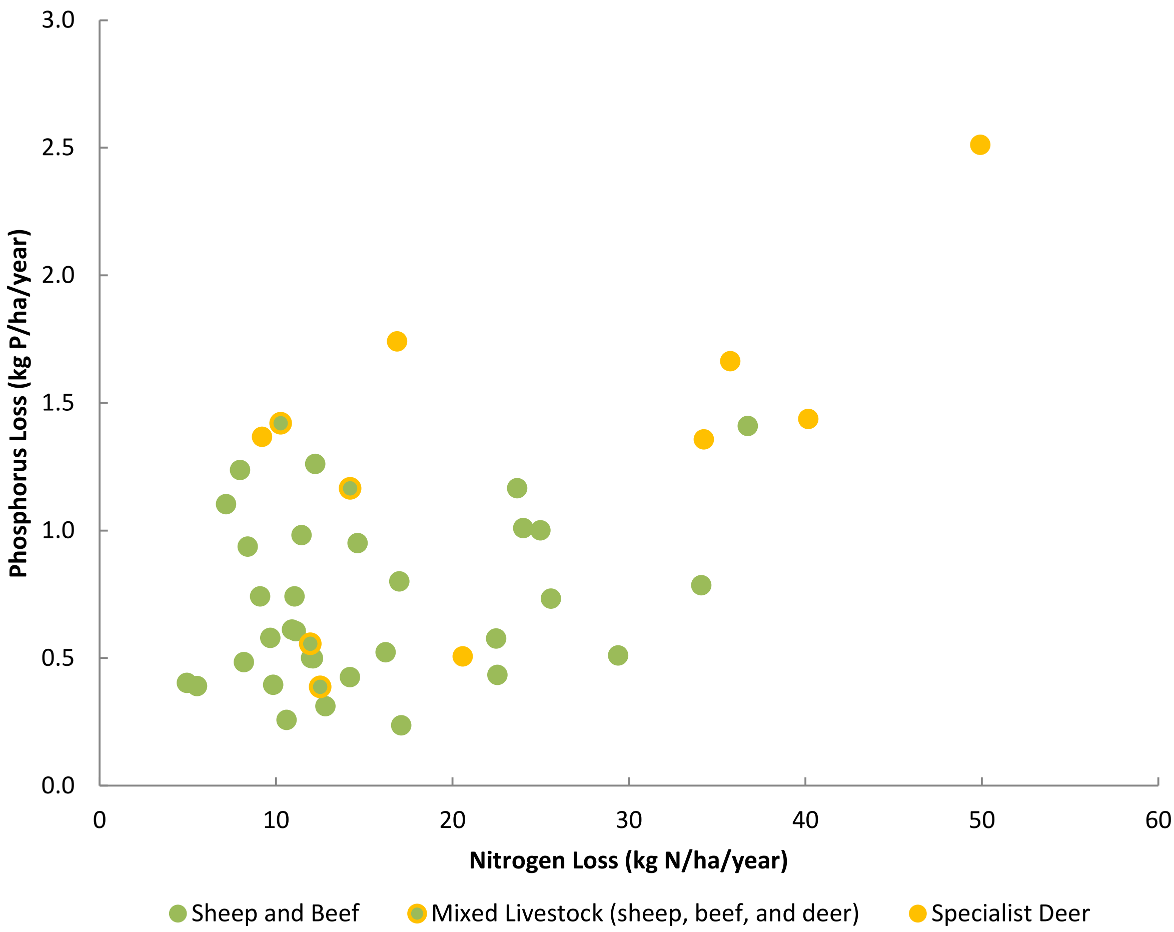

Figure C16: Baseline nitrogen loss and phosphorus loss for 43 drystock farms

The complexities and diversity of drystock farming made it challenging to identify specific factors that drive nutrient losses across the case study farms. Multiple factors can contribute to nutrient losses and there is a different combination of factors for each farm. However, the following section explores some of these factors for nitrogen.

2.4.5. Possible Factors Driving Nitrogen Losses

Section 2.2 outlined key characteristics of the case study farms that are relevant to both the baseline and mitigation modelling: farm size and topography, rainfall and soil drainage, proportion of ineffective area, proportion of effective area in crop, and livestock mix. These farm characteristics influence how OVERSEER estimates nutrient loss but it is not easy to identify patterns in the results from a set of case studies because of the complexity of each farm's production system. Possible additional factors not included in the description of farm characteristics are stocking rates and fertiliser use.

Three case studies are briefly described below to illustrate the complexity - the annual rainfall for all three farms was over 1,000 mm.

Farm 8 was the sheep and beef farm with the highest nitrogen loss of all the sheep and beef farms. It was a medium-size farm and almost all of it is effective area. The farm was split between well-drained flat land and moderately well-drained hill country. It had a stocking rate of around 6 SU per effective hectare, a relatively low proportion of effective area in crop, and earned revenue from dairy grazing.

Farm 42 had the highest nitrogen loss of all the sheep, beef and deer case study farms. It was a small to medium-size deer farm with a relatively high proportion of effective area. The farm was on poorly drained soils, evenly split between flat and hill land. It had a stocking rate of between 7 and 8 SU per effective hectare and one of the highest proportions of effective area in crop.

Farm 4 had the lowest nitrogen loss of all the drystock farms and was a small farm, with a low proportion of effective area. The farm is on poorly drained flat land. The farm had a stocking rate of around 10 SU per effective hectare and a relatively low proportion of effective area in crop.

Slope, Rainfall and Drainage

In general across the 43 drystock farms modelled there was no clear relationship between nutrient losses and the broad slope classes used for farm selection (LUC Classes 1-4 and Classes 5-7), or the broad rainfall categories used for farm selection (rainfall under 1000 mm a year and rainfall over 1000 mm per year).

Soil drainage can be an important factor in facilitating movement of nutrients dissolved in water; soils with good drainage have greater risks of nutrient loss when soil moisture content is high. To explore the influence that soil type and soil drainage class can have on the results, the following desktop exercise was undertaken.

When Farm 8 was modelled, its baseline loss was 37 kg N/ha/year and 0.4 kg P/ha/year, which was the highest nitrogen loss for sheep and beef farms (excluding deer). To understand the factors contributing to this result, all aspects of the farm (stocking rate, stock weights and sales, fertiliser application, pasture type, cropping, stock grazing timing etc.) were investigated. In these investigations, one step was to alter the farm's soil class and drainage from medium and well-drained soils to poorly drained soils. This step decreased losses from 37 kg N/ha/year and 0.4 kg P/ha/year to 20 kg N/ha/year and 0.3 kg P/ha/year. However, poorly drained soils in Southland usually have artificial drainage, which accelerates the loss of nitrogen dissolved in water, while phosphorus is more likely to adhere to soil particles. The farmer was already using younger and lighter stock so as to not damage his soils. The rest of Farm 8 remained unchanged, including farm management decisions. The impact of changing the soil class and drainage on profitability was not investigated.

This desktop sensitivity analysis exercise highlights that there are components within a farm production system that are drivers of nutrient loss that the farmer has little control over and cannot adapt without investment in mitigations such as infrastructure or wetlands.

Stocking Rates

There was also no clear relationship between nutrient losses and stocking rates. The stocking rate for all but one of the case study farms was less than 15 SU per effective hectare. The average stocking rate for the 43 farms was 9.4 SU/eff.ha and the median was 9.5 – or roughly equivalent to 1.2 dairy cows per effective hectare. Farm 42 had the highest nutrient losses of the case study farms and a stocking rate of 7 SU/eff.ha, which is below the average and median stocking rates of nine SU per effective hectare across all 46 drystock farms. By comparison, Farm 17 has a stocking rate of 19 SU/eff.ha and a nitrogen loss of 13 kg N/ha/year and a phosphorus loss of 0.4 kg P/ha/year.

The stocking rates for the drystock farms reflect the carrying capacity of the land. Almost all sheep, beef and deer farmers in Southland are self-sufficient in their feed needs, which they produce on-farm. Some have all-grass wintering systems (i.e. they conserve feed when pasture production is high and feed it out as needed in winter), while others grow winter feed crops. In both situations, farmers adapt their livestock numbers and farm management systems to the land and seasonal growing conditions. Overall, sheep, beef and deer farmers spend a very small amount on imported feed, mostly in the form of sheep or deer nuts and some hay. (Jenny McGimpsey pers.comm., 2017).

Proportion of Ineffective Area

The nitrogen and phosphorus loss results are reported for a farm's total area. Research has shown that ineffective areas of a farm usually have low nutrient losses in comparison to the areas actively used for production, and this is what is assumed in OVERSEER. As a result, the ratio of a farm's ineffective hectares to effective hectares has an impact on its nutrient loss per hectare. Overall, ineffective areas reduced a farms total nutrient loss by an average of 2 kg N/ha/year (median of 0.9 kg N/ha/year) and 0.1 kg P /ha/year (average and median).

Cropping Area

There is some relationship between the nutrient loss results and proportion of effective area in crop. Most farms had 11% or less of effective area in crop and six farms had considerably more effective area in crop, although two of these farms could not be modelled. The four farms modelled with relatively high proportions of effective area in crop had relatively high nitrogen losses and two of these farms also had higher phosphorus losses. Farms with lower proportions of crop area but with nutrient losses above 20 kg N/ha/year are likely to have other factors at play.

Farm Size

Although the complexity of the farms makes it challenging to identify patterns, there were at least four factors that appear to be related to nitrogen loss for the 36 sheep and beef farms modelled:

farm size, the raising or grazing of dairy cows, and to a lesser extent, proportions of ineffective area or effective area in crop. Any similar patterns for phosphorus losses were less clear.

The 36 sheep and beef farms fell into two groups:

Group 1: Nine larger farms (more than 1,000 effective hectares). These farms had nitrogen losses of 15 kg N/ha/year or less. On average, these farms had a stocking rate of 8.5 SU/eff.ha, although two farms had high stocking rates in comparison to the sheep and beef farms as a whole. The farms also had average ineffective areas of just under 12% of the total area and an average effective area in crop of 6.5%.

Group 2: 27 smaller farms (less than 1,000 effective hectares).These farms had nitrogen losses that were more evenly spread.

Figure C17 shows the nitrogen loss and profitability for sheep and beef farms by farm size.

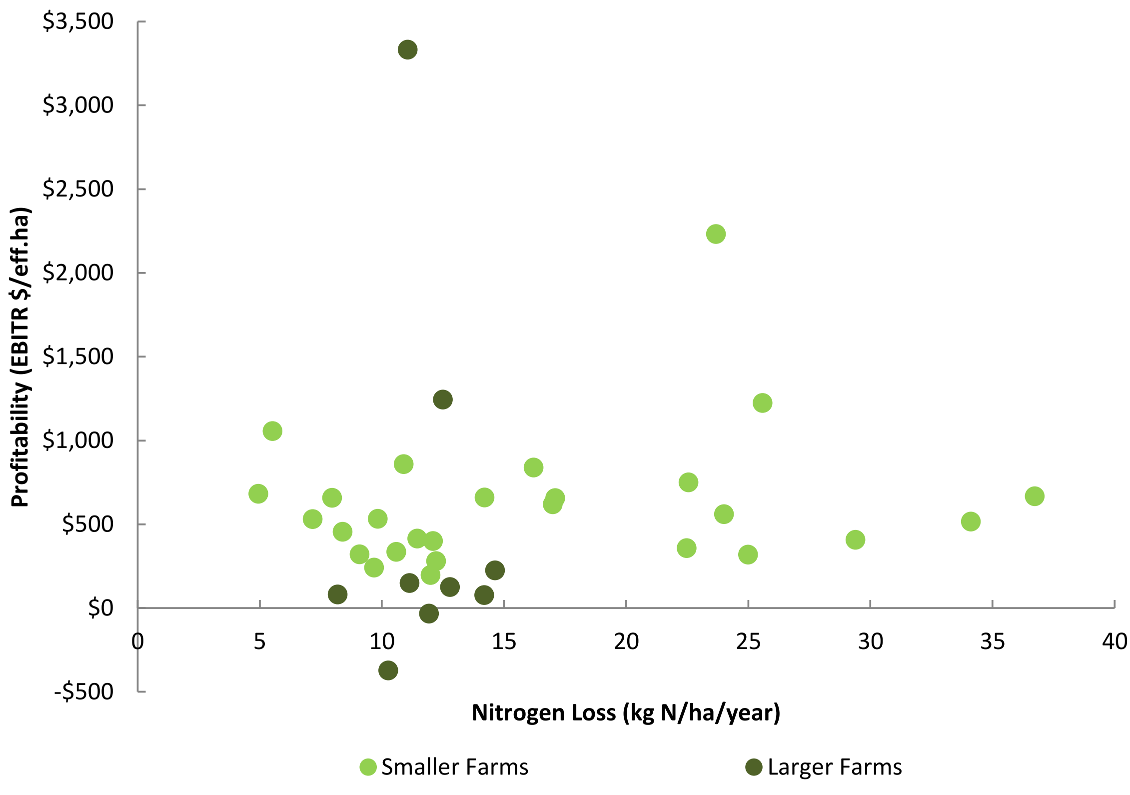

Figure C17: Nitrogen loss and profitability by farm size for 36 sheep and beef farms

Smaller Farms

The second group of 27 smaller sheep and beef farms (less than 1,000 effective hectares) then fell into farms with nitrogen losses either below or above 20 kg N/ha/year (with a 5 kg gap between the two):

Group 2a: 18 farms had nitrogen losses below 20 kg N/ha/year. These farms had a mix of soil drainage types and an average stocking rate of 10.5 SU/eff.ha. The farms also had an average ineffective area of just under 13% of total area and an average effective area in crop of 6%. Five farms either earned revenue from dairy grazing and/or had dairy cattle at the start of the farming year.

Group 2b: Nine farms had nitrogen losses above 20 kg N/ha/year. These farms had a mix of soil drainage types and an average stocking rate of 8.3 SU/eff.ha. The farms also had an average ineffective area of just over 5% of total area and an average effective area in crop of almost 11%. All of these farms either earned revenue from dairy grazing and/or had dairy cattle at the start of the farming year.

It is not necessarily the case that the nitrogen losses of these nine smaller farms are as a result of raising or grazing dairy cows – they may be indicative of a more intensive management style or system type on these sheep and beef farms. Figure C18 shows the 27 smaller sheep and beef farms by whether or not they raised and/or grazed dairy cows.

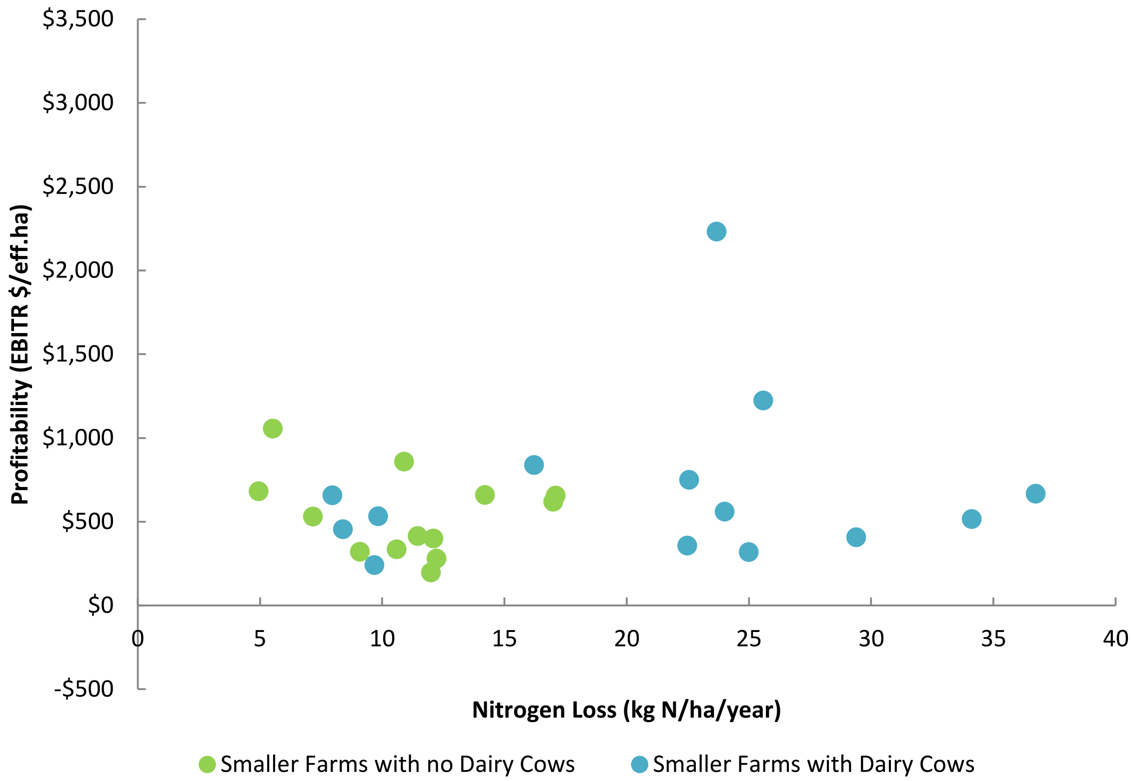

Figure C18: Distribution of dairy cows on sheep and beef farms with less than 1,000 effective hectares

The research did not investigate the extent to which farm area and the raising and/or grazing of dairy cows contributed to nitrogen losses.

2.5. Mitigation Scenarios

Drystock farms have limited use of inputs, such as nitrogen fertiliser on pasture and imports of low protein feed (palm kernel and maize silage), in their production systems. Also, their livestock is wintered on-farm (sometimes with the inclusion of dairy cows) and off-paddock structures like stand-off pads and wintering barns are rare. Consequently, there were only a few mitigations available for modelling. Overall, four mitigations were considered: three for sheep and beef farms and one additional for deer farms. Each of the mitigations was modelled in turn on each farm using the same modelling rules.

The mitigation options considered for the drystock case study farms were:

Nutrient Inputs	(Section 2.5.1)
Crop Policy	(Section 2.5.2)
Stock Policy	(Section 2.5.3)
Fence Pacing and Wallowing (deer farms only)	(Section 2.5.4)

The focus of the modelling was identifying the impact of available mitigations for drystock farms. The approach was to identify the least-cost option for each farm, based on analysis of the information collected during the farm visit, and to model the mitigations separately. The farm visit was important because information on decision-making, such as the history of the farm and future, was collected and discussed. This information was used to guide how mitigations were modelled for a farm.

The mitigations were modelled separately, rather than being added together (cumulative) to give stepped reductions in nutrient losses. This approach suits the complexity and diversity of drystock farm businesses, and meant fewer assumptions had to be made about the mix of factors that influence farmer decision-making. In reality, individual farmers will respond to policy in ways that best suit the multiple objectives they have for their farm business (commercial, social, family, and environmental). This response is more involved than can be established through a modelling process but provides useful insights into what are complex businesses.

2.5.1. Nutrient Inputs

Generally, the first mitigation modelled for nutrient inputs was that which was estimated to have the least impact on profitbaility, e.g. shifting application of fertiliser from autumn to spring. It has little, if any, financial impact because it is 'simply' a matter of changing the timing of application. However, individual farmers best know their situation in respect of physical and other constraints and their individual short and long-term farm business and family objectives. For example, moving fertiliser applications from autumn to spring may be financially restricted; it may not be possible or practicable on all or some portion of a farm because of weather (and thus farm conditions), stocking rates and production objectives.

No capital applications of fertiliser were applied, regardless of the fertility status of the block/farm. Only maintenance applications were modelled (and maintenance levels as stated by OVERSEER).

Applications were split when application rates were deemed high following the OVERSEER Code of Practice for Nutrient Management (with emphasis on fertiliser use) (Fertiliser Association, 2013). Where applicable, the use of reactive phosphate rock (RPR) (a type of fertiliser) was implemented. Nutrients that were applied but were not nitrogen or phosphorus were not included in the modelling.

Nitrogen fertiliser mitigation modelling steps:

Step 1: Reduce Autumn nitrogen application rates (replace lost pasture production by using supplements and/or reducing stock numbers);

Step 2: Remove Autumn nitrogen application (replace lost pasture production by using supplements and/or reducing stock numbers);

Step 3: Reduce Spring nitrogen application rates (replace lost pasture production by using supplements and/or reducing stock numbers); and

Step 4: Remove Spring nitrogen application (replace lost pasture production by using supplements and/or reducing stock numbers).

Phosphorus fertiliser mitigation modelling steps:

Step 1: Ascertain soil fertility;

Step 2: Mine Olsen P levels to agronomic optimum (if above an Olsen P of 30);

Step 3: Reduce fertiliser application to maintenance levels only (regardless of fertility);

Step 4: Change application from autumn to spring; and

Step 5: Split application rates if over 300kg/ha.

2.5.2. Crop Policy

The crop policy mitigation was implemented by using OVERSEER to identify which crop blocks were to be modelled. This was achieved through a number of modelling steps – which were implemented by reducing the crop area, and required replacing lost dry matter with other feed. This is consistent with other modelling that has taken place.

The least-cost option (as modelled through FARMAX) was either increasing the amount of baleage made and fed, or reducing stock numbers, and sometimes a combination of both, particularly on farms with limited ability to produce more baleage. If the farmer had indicated a future change in crop policy, this was taken into consideration when modelling, e.g. changing to fodder beet and reducing the crop area, or not continuing with dairy grazing.

Winter cropping in Southland is very complex. It differs across the region, planted on different slopes and soils, cultivated differently, managed as a one-year crop or part of a multiple year rotation, fed to different stock enterprises or livestock classes at different times of the year, or harvested as a grain/cereal silage/hay. OVERSEER may not always be able to model these complexities.

As an example, lucerne was grown on some case study farms as a safe summer feed but in OVERSEER it is treated as pasture rather than a crop. Nitrogen losses from lucerne are higher than normal pasture so separate lucerne blocks were created for the modelling but it was usually grown over smaller areas so did not have a noticeable effect on a farm's losses.

In reducing stock numbers, dairy cattle were targeted first if a farmer had indicated they did not want to continue dairy grazing. If this intention had not been indicated then sheep/cattle/dairy stock numbers were reduced to achieve the least-cost option. It could be that the numbers were spilt between the different stock enterprises, or targeted one in particular, depending on the cost to feed the different stock types.

Modelling steps:

Step 1: Identify which cropping block has the highest nitrogen and phosphorus loss (either by hectare or total loss);

Step 2: Improve cropping practice/change crop grown (if indicated by farmer e.g. swedes to fodder beet) to increase yield;

Step 3: Reduce area of crop grown (by up to 25%);

Step 4: Replace lost dry matter production by increasing baleage harvested on farms and/or decreasing stock numbers.

2.5.3. Stock Policy

There are two aspects to the stock policy mitigation. The first stock mitigation was to 'shift' heavier stock from grazing on particularly vulnerable soils (i.e. those vulnerable to nutrient loss) and slopes during winter to see what impact it may have on leaching/runoff losses. This mitigation was not applicable to all farms (because of practical issues, such as some farms may be all hill, or a single soil type), and it did not have a financial component.

The second stock policy mitigation was to reduce all livestock numbers by 10% (no one stock type was specifically targeted). This mitigation was modelled in isolation (i.e. no other inputs were altered as a result of the reduction in stock) to determine the impact of reducing stock numbers on nutrient loss rates and profitability. This mitigation is different to the first stock policy mitigation as feed was necessarily balanced in the modelling. It was modelled in response to a request by Environment Southland to investigate the relationship between stock numbers, nutrient loss and profitability.

Modelling steps:

Step 1: Shift heavier stock (mixed age cattle) off vulnerable slopes (if possible);

Step 2: Reduce/remove dairy stock numbers (if feasible); and

Step 3: Reduce all stock numbers by 10%

2.5.4. Fence Pacing and Wallowing - Deer

The ability to model fence pacing and wallowing is a coarse tool in OVERSEER. It is represented by two 'tick box' questions, where there is no ability to identify the degree that the deer pace fences, or how many wallows and if they are connected to waterways. Unless the farmer surveyed could demonstrate that none of the behaviours occurred, it was recorded in OVERSEER that it did take place. To model this mitigation, farm maps were used to identify and estimate the length of waterways that a farmer would need to fence. It was then assumed that 10% of the unfenced waters on a farm could be 'deer fenced' in a year, and once fenced this area would be free from fence pacing and wallowing.

The 10% assumption and the fencing costs were determined in consultation with a Southland deer farmer with extensive industry knowledge. Different cost structures were used for flat/rolling hill country and steeper hill topography, recognising the increased cost when fencing more difficult country. For some farms, this mitigation was a considerable cost, because not only was fencing the hill country expensive, but also they had extensive areas to fence. The fencing cost was then included in the calculation of the farm's profitability (EBITR). The water reticulation for stock drinking water was not included in the mitigation cost.

Modelling step:

Step 1: assume 10% of the total farm area with identified waterways is fenced.

2.5.5. Farm Examples

This section directly compares the farm characteristics and the mitigation modelling of two different sheep and beef farm systems (Table C12). The two farms were chosen to illustrate different complexities in both their farm systems and how the same mitigations were modelled on these farms.

Table C12: Farm examples

	Farm A	**Farm B**
General Land Information	**Land Use Capability Class:** LUC 1-4, 100% Flat	**Land Use Capability Class:** LUC 5-7, 100% Hill country – 64% Rolling, 36% Easy Hill (OVERSEER slope classes).
	Ineffective Areas: Wet tussock areas, not grazed. **Rainfall:** 1,200 mm/year (NIWA). **Physiographic Zone:** Lignite/Marine Terraces.	**Ineffective Areas:** Native Bush, not grazed. **Rainfall:** 1,100 mm/year (NIWA). **Physiographic Zones:** Bedrock-Hill Country, Oxidising, and Gleyed zones.
Size	**Total area:** 100 to 200 hectares. **Effective area:** 120 hectares.	**Total area:** 1,000+ hectares. **Effective area**: 930 hectares.
Soil and Drainage	**Soil:** Brown, Silt loam. **Drainage:** Imperfect, occasional pugging, 100% mole and tile system.	**Soil:** Brown, Silt loam. **Drainage:** Moderately well, occasional pugging, 50% mole/tile system with one open drain.
Pasture and	**Pastures:** Ryegrass, white clover, plantain and chicory. High quality pasture, spring pick up 2nd	**Pastures:** Ryegrass, white clover, cocksfoot. Medium quality pasture, spring pick up in October,

	Farm A	Farm B
Supplements	week of spring, December peak growth, good summer growth, reasonable winter growth. 20 hectares of new grass a year, aims to do 8% of the farm annually.	peak growth months November and March. Summer production is moisture-dependent, survey year was average growth. Growth drops off mid-April with minimal growth in winter. The steeper paddocks are lagging behind in pasture quality and quantity – are currently working on changing this. 50 hectares of new grass a year following the crop.
	Supplements: 14 hectares of baleage – 200 bales. 4 tonnes of sheep nuts (bought).	**Supplements:** 36 hectares of baleage – 400 bales.
Soil Test and Fertiliser	**Soil Test:** Regular soil testing.	**Soil Test:** No tests (average fertility estimated by OVERSEER).
	Olsen P: 18 mg/ml. **Fertiliser:** Mix of fertilisers. Nutrients are being applied at just under maintenance in Autumn.	**Olsen P:** 16 mg/ml. **Fertiliser:** Lime and Superphosphate in February. Applied by truck on the rolling country and by plane for the steeper paddocks.
Crop	No crop this year. Rotational grazing in winter.	Two-year crop rotation, 100 hectares of turnips/kale/grass. All stock grazed on winter crops, with the sheep on the turnips to start, and cattle to clean up. Kale is equally grazed by both. The 80 mixed age cows were grazed for four weeks from Mid-August.
Stock	**1,362 Sheep SU; No Cattle** **Sheep:** 1,088 ewes, 135% lambing, composite breed.	**11,212 Sheep SU; 2,465 Cattle SU** **Sheep:** 9,479 ewes, 130% lambing, traditional breed.
	Lambs finished on the farm and sold prime. Average carcass weight 18.8 kg.	Mix of store and prime lambs. Average carcass weight 17.4kg. **Cattle:** Beef cross, 240 Breeding cows. 253 other cattle (rising one year-olds, rising two-year-olds, steers, bulls).
Profitability (EBITR)	$759 per effective hectare.	$183 per effective hectare.
Nutrient Loss	**Nitrogen:** 14 kg N/ha/yr. **Phosphorus:** 0.4 kg P/ha/yr.	**Nitrogen:** 29 kg N/ha/yr. **Phosphorus:** 0.5 kg P/ha/yr.

The two farms differed in every aspect of the farm system. The mitigation modelling followed the same steps for each farm but were applied in ways that reflected the farm system (Table C13). This comparison as used as an example of how each farm was modelled based on how it was currently being farmed, without changing the farm system.

Table C13: Mitigation comparison

	Farm A	Farm B
Nutrient Input	**Not applied** **Reason:** Sub-maintenance fertiliser, not enough to warrant reduction.	**Was applied:** 2% reduction in nitrogen and phosphorus loss, 9% reduction in profitability (EBITR/ eff.ha) **Reason:** Reduce fertiliser application to maintenance. Small increase in profitability due to less fertiliser bought. *Note: This is a short-term option that will result in a reduced ability to grow pasture if the soil fertility is allowed to continue to be mined.*
Crop Policy	**Not applied** **Reason:** No crop	**Was applied:** 19% reduction in nitrogen loss, 1% reduction in phosphorus loss, 27% reduction in profitability (EBITR/ eff.ha). **Reason:** Several different iterations of this mitigation were modeled. The aim of the modeling was to achieve a nutrient loss reduction, while applying the least-cost option. The ability to complete a two year cropping rotation was removed (a larger new grass area will result, included the extra cost). The areas of both crops were reduced as they were equally high loss due to both sheep and cattle grazing (at different intensities). The lost dry matter production was then replaced through FARMAX modeling to ascertain the least-cost option. This was a mix of an increase in baleage made on the farm, the mixed age dairy cows were removed, and a decrease in sheep numbers by 10%.
Stock Policy	**Was applied:** 8% reduction in nitrogen, 2% reduction in phosphorus, 24% reduction in profitability (EBITR per eff.ha). **Reason:** Reduce numbers of all stock by 10%.	**Was applied:** 7% reduction in nitrogen loss, 3% reduction in phosphorus loss, 34% reduction in profitability (EBITR per eff.ha) The mixed age dairy cows have been removed. Reduce numbers of all other stock by 10%. **Reason:** Reduce numbers of all stock by 10%

2.5.6. Assumptions

Some assumptions were used for the modelling. First, the farmer's actual data was used at all times within the modelling. No attempt was made to smooth or adjust the data because the idea was to represent the farms as they happened in real time. No assumed price was used for prime and live sales of lambs/cattle/deer and velvet, the actual prices received were used. The fertiliser prices actually paid by the farmers were used with no adjustments.

Some other analyses have included value judgements by analysts/consultants about what is 'typical', e.g. the typical livestock mix, typical maintenance and capital fertiliser applications, typical weights and prices for outputs such as prime lambs, wool, cattle or other products. As discussed earlier, drystock farms are complex with multiple enterprises, livestock classes and inputs so one analyst's 'typical' is not another's.

Secondly, when it came to mitigation modelling, it was assumed that the labour on the farms would remain consistent, because labour is a 'lumpy' input and a significant majority of the farms were run by owner/ operators with very few (if any) staff. It was also assumed throughout the mitigation modelling that the live weights throughout the year, the finishing and sale weights of the stock, would also be consistent.

The mitigation modelling did not include the retiring of land as an option (i.e. the modelling stopped if the next mitigation was to retire substantial areas of land from production. We did not investigate with the farmers if, when, how and where retirement of land could occur.

For each farm, the first mitigation tested was the least-cost mitigation, which was determined on a farm by farm basis using the knowledge obtained from the farmer in this project. However, the approach adopted may or may not be that which the individual farmer may adopt to respond to council policy depending on the final nature of the policy, and his or her wider objectives for the farm business, e.g. family, succession, way of life, development strategy.

By using OVERSEER and FARMAX software, all assumptions built into those models were implicitly adopted. As described earlier, all the data was actual as occurred in 2013-14 – from the B+LNZ Sheep and Beef Farm Survey for 2013-14 or from discussion with the farmer, where the farm was not part of the Survey. This applies equally for OVERSEER and FARMAX. There was some interpretation of the baseline data, to be able to create 'blocks' within OVERSEER, which was done in accordance with the best practice input data standards. (BPDIS (2015) OVERSEER Best Practice Data Input Standards, OVERSEER version 6.2.0, May 2015, OVERSEER Limited).

2.5.7. Limitations and Constraints

The most basic limitation is that the research uses a sample of the total population of farms and farmers in Southland that may need to mitigate their nutrient losses in the future as a result of setting environmental limits for water.

Second, the use of OVERSEER and FARMAX means using the assumptions, limitations and constraints of those models. These limitations include: not estimating attenuation or dilution of nutrients between the root zone or farm boundary and the eventual receiving water body, not accounting for extreme events (floods and droughts), soil information from S-Map not being available for all farms, in-paddock management techniques are not able to be modelled, accepting known 'bugs' that can make modelling farms difficult does not allow for mixed pasture sward (e.g. ryegrass, white clover, cocksfoot, or plantain).

The modelling is based on case studies because of limited resources but relies on statistical methods to estimate variability. Generally, the discipline of statistics reduces such uncertainty, but absolute knowledge cannot be assured unless the entire population of farms across the region and across the timeframes envisaged by policy measures are surveyed, studied, and analysed.

The analysis here is limited because it is a snapshot of one financial year (2013-14). Inevitably, product prices and expenditure vary from year to year in response to many factors. Further, individual farmer responses to those prices, and their expectations of future prices – for both outputs and inputs – may influence their ability to respond to policy measures.

The analysis is also somewhat limited by the information gathered in this process never being able to fully represent the nuances of human behaviour of individual farmers and their response – individually and collectively. Modelling farms as profit maximising enterprises ignores individual preferences and values which are unable to be modelled but are discussed in Section 2.6.3.

The complexity of drystock farms means there is a very large number of permutations of assumptions that could be tried with each set being unique for each individual farm, and doing so would provide little reward for the effort involved. Nevertheless, the use of data from farms across Southland provided a more robust baseline than could have been done using models of 'typical' or 'average' farms, which inevitably reduces the level of complexity that exists in reality.

This individuality will mean that farmers likely will not identify a case study farm that is exactly the same as their own, but will be able to look across a number of farms and get a feel for the effectiveness and impacts of different mitigations on their farm based on the results on those in the case study sample.

The level of farm infrastructure varies throughout the case study farms, once again highlighting the complexity of drystock farms. One farm has irrigation on a small block for the purpose of summer-proofing the business. The reason and levels to which waterways are fenced are quite variable, but ensuring access to stock drinking water while minimising environmental issues seemed to be of great concern. The use of feed pads on the sheep and beef farms was minimal, but these were implemented on the deer farms in some areas.

The farm visits and data collection took place in 2015, well before the proposed Southland Water and Land Plan 2016 was released, and 'limits' for fresh water were not yet fully on farmer 'radars'. However, most farmers were aware that 'limits' were coming, and there were discussions about what had happened in other parts of the country, and how it might play out in Southland.

2.6. Mitigation Results

This section presents the mitigation results for the 43 drystock case study farms – there are up to four mitigation results for each farm because a farm had four mitigations modelled on it. The results are shown by mitigation rather than by farm because of the complexity involved with linking individual mitigations together. However, Figure C28 and Figure C29 (at the end of Section 2.6.1) and Figure C38 and Figure C39 (at the end of Section 2.6.2) are included to show sets of mitigations for both Nitrogen and Phosphorus for particular farms where all three mitigations were achieved..

The mitigation results are given as absolute changes in nutrient loss and profitability from the baseline (e.g. -5 kg N/ha/year). Percentage changes are also reported but because the baseline nutrient results were often relatively low (median nutrient loss rates were 13 kg N/ha/year and 0.7 kg P/ha/year) care needs to be taken in interpreting these results as they do not necessarily translate into changes that are meaningful in absolute terms (i.e. within margins of error). Overall, there is considerable variation in the changes in nutrient loss and profitability between both the farms and the mitigations.

Across the 43 drystock farms, the mitigations resulted in changes in profitability in all directions (including no change). Table C14 gives average and median changes in profitability for the sheep and beef farms and the deer farms modelled with that mitigation. All of these results are farm results but are reported by effective hectare.

Table C14: Number of farms modelled with each mitigation and the change in profitability (EBITR $/eff.ha)

Mitigations	Number of farms	Sheep and beef farms		Deer farms	
		Average	Median	Average	Median
Nutrient Inputs	**32**	+$40 (7%)	+$5 (1%)	+$55 (14%)	+$31 (11%)
Crop Policy	**37**	-$42 (9%)	-$35 (8%)	+$12 (0%)	+$7 (2%)
Stock Policy	**43**	-$105(24%)	-$96 (22%)	-$110 (33%)	-$129 (35%)
Fence Pacing and Wallowing	**6**	N.A.	N.A.	-$82 (27%)	-$50 (27%)

2.6.1. Nitrogen

Table C15 gives the number of farms modelled with each of the mitigations and the distribution of nitrogen loss results. The mitigations usually either decreased or had no effect (0 kg column) on a farm's nitrogen loss. They tended to have more effect on some of the smaller farms because these farms had higher baseline losses. In three cases, specific mitigations increased the nitrogen loss on a farm (+5-0 kg column) either because the mitigation was designed to target phosphorus or because of a 'bug' in OVERSEER that was unable to be rectified.

Table C15: Number of farms with each mitigation and change in Nitrogen Loss (kg N/kg/year)

Mitigations	Number of farms	+5 to 0 kg	0 kg	0 to -1kg	-1 to -5 kg	-5 to -10 kg	-10 to -15 kg
All farms <1,000 eff.ha							
Nutrient Input	**24**	0	12	6	5	1	0
Crop Policy	**32**	0	0	11	17	3	1
Stock Policy	**33**	1	0	18	13	0	1
Fence Pacing	**5**	2	3	0	0	0	0
All farms >1,000 eff. ha							
Nutrient Input	**8**	0	4	4	0	0	0
Crop Policy	**5**	0	0	4	1	0	0
Stock Policy	**10**	0	0	10	0	0	0
Fence Pacing	**1**	0	0	1	0	0	0
Totals							
Nutrient Input	**32**	0	16	10	5	1	0
Crop Policy	**37**	0	0	15	18	3	1
Stock Policy	**43**	1	0	28	13	0	1
Fence Pacing	**6**	2	3	1	0	0	0

The results showed that a farm's 'start point' (or baseline nitrogen loss) influenced the effectiveness of each of the mitigations. In other words, there was a positive relationship between a farm's baseline nitrogen loss and the amount of change from a mitigation. A mitigation tended to be more effective if a farm started with a higher baseline loss, and conversely it tended to be less effective if a farm started with lower baseline loss. This relationship appeared to hold for all of the mitigations modelled except for the fence pacing and wallowing mitigation, which is unsurprising as this mitigation targets phosphorus losses. Figure C19 shows the farm start points for the four mitigation and the change in nitrogen losses from each mitigation – the mitigation results are plotted by a farm's baseline nitrogen loss (on the x-axis) and the amount of change from a mitigation (on the y-axis). In general, the distribution of the data points suggests a downward slope from left (lower baseline nitrogen losses) to right (higher baseline nitrogen losses), indicating a positive relationship.

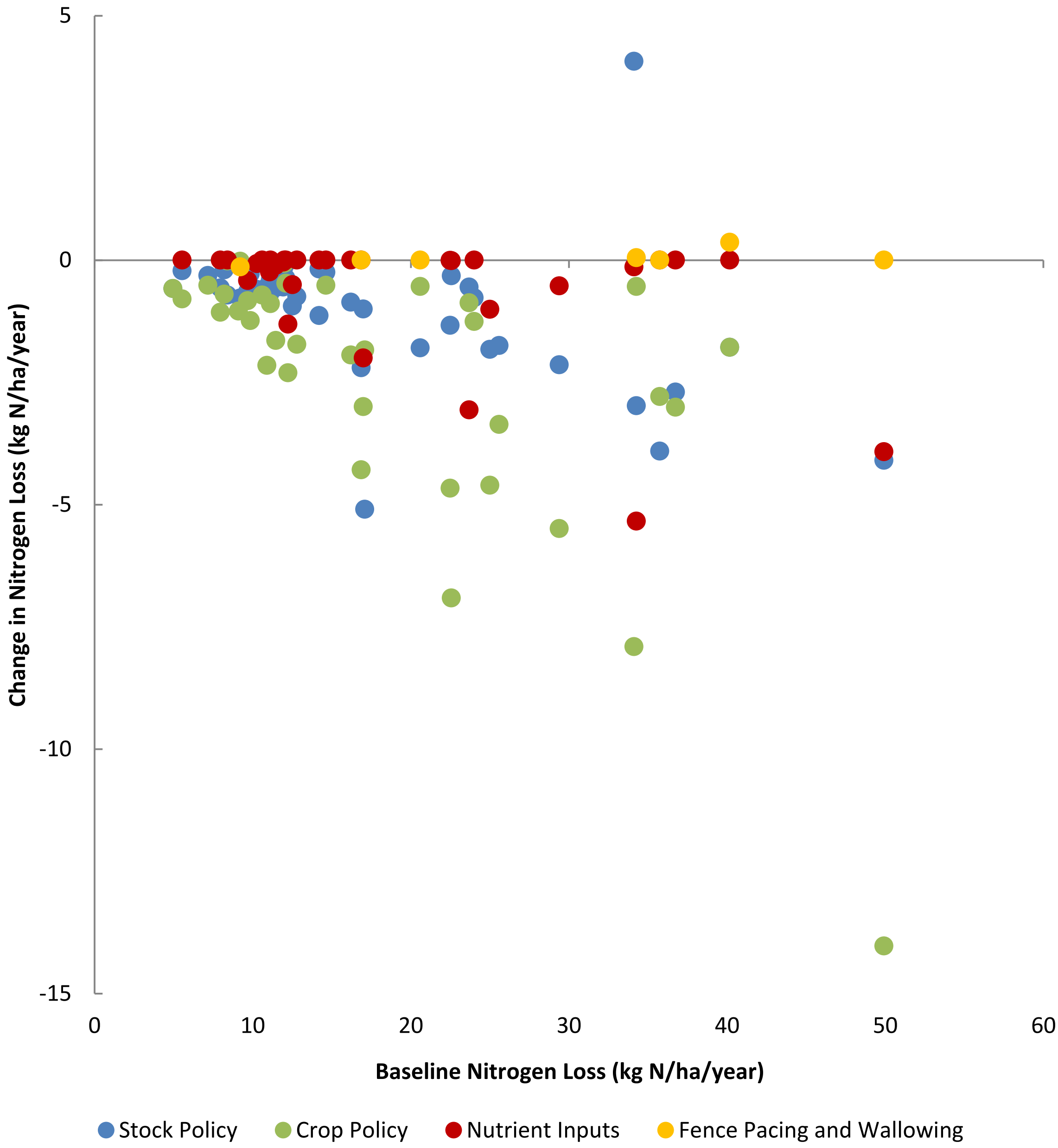

Figure C19: Relationship between baseline nitrogen loss and change in nitrogen loss for 43 drystock farms

While the results indicate a positive relationship between a farm's baseline nitrogen losses and the effectiveness of mitigations, they show no link between a farm's 'start point' (or baseline nitrogen loss) and how a mitigation changed its profitability. Although the mitigations reduced profitability in most cases, there appeared to be a neutral relationship between a farm's baseline nitrogen loss and the amount a mitigation changed profitability. In other words, the change in profitability appeared to be independent of the farm's start point. Figure C20 shows the baseline nitrogen losses and the change in profitability from the four mitigations – the mitigation results are plotted by a farm's baseline nitrogen loss (x-axis) and its change in profitability from each mitigation (y-axis). In general, the distribution of the data points suggests it is roughly level from left (lower baseline nitrogen losses) to right (higher baseline nitrogen losses).

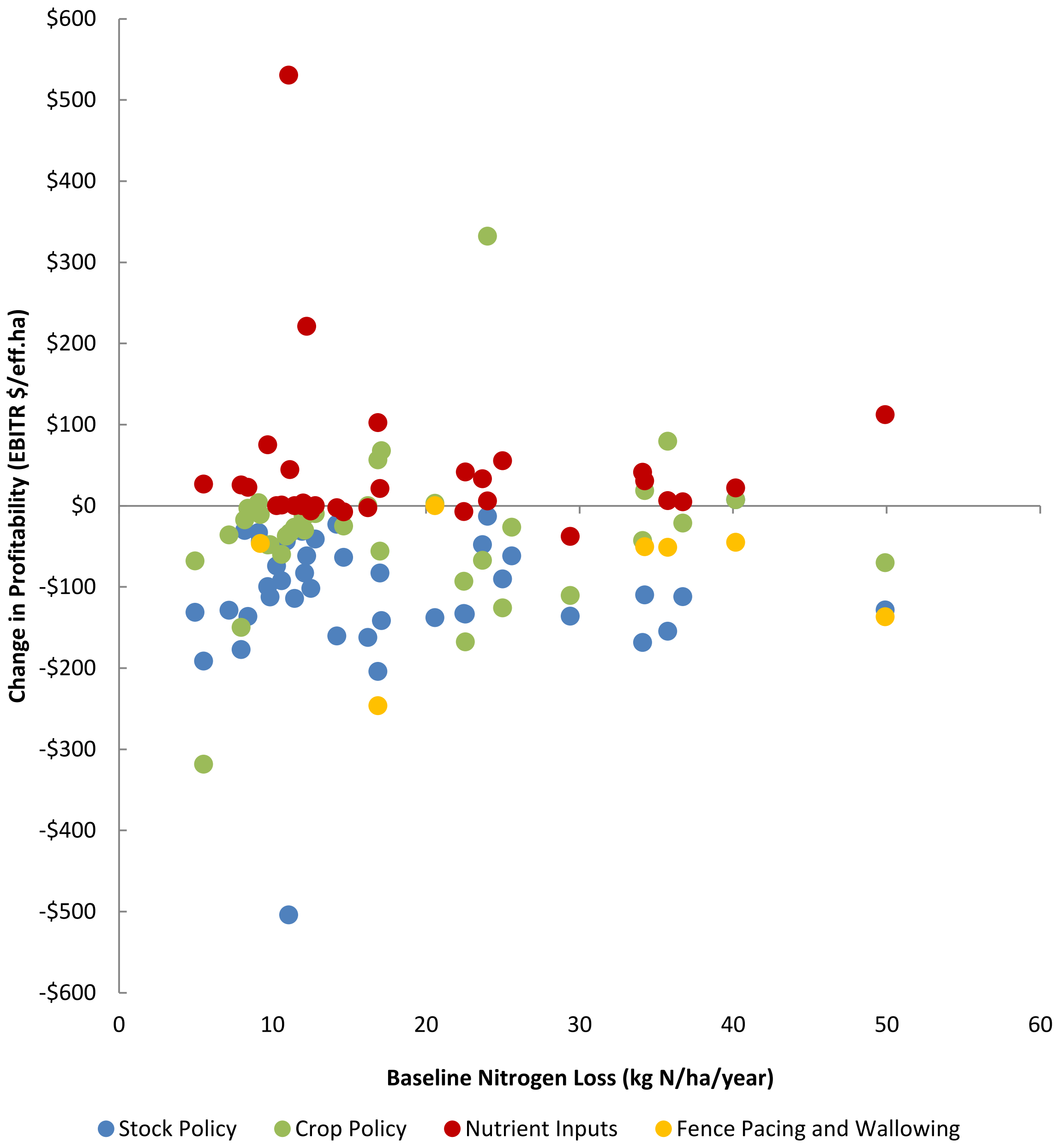

Figure C20: Relationship between baseline nitrogen loss and change in profitability for 43 drystock farms

The impact on profitability from the nutrient inputs, crop policy, stock policy and fence pacing and wallowing mitigations were roughly similar, regardless of whether a farm had higher baseline nitrogen losses or lower losses (although there some outliers). When these two graphs are considered together, they suggest that the mitigations appeared to be less effective on farms with lower baseline losses, but the impacts on profitability were at least similar to mitigations on farms with higher baseline nitrogen losses.

As well as there being different relationships between a farm's baseline nitrogen losses and the effectiveness and impacts of mitigations, there are clear patterns between each of the four mitigations. Figure C21 shows the changes in nitrogen loss and profitability for each mitigation – the distance each data point is from '0' indicates how much a mitigation changes a farm's nitrogen losses and profitability from its baseline. Figure C22 shows the results as percentage changes.

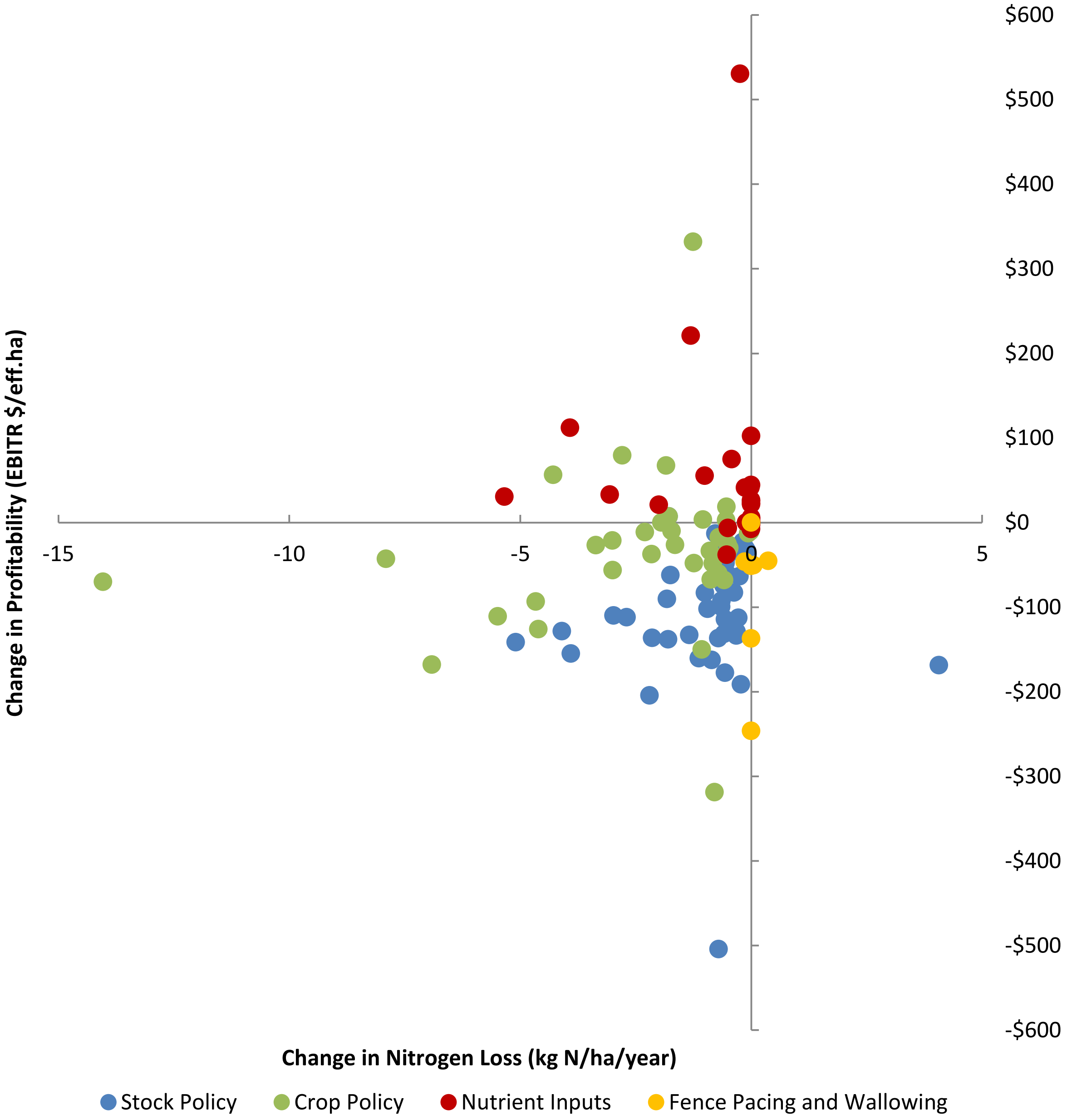

Figure C21: Change in nitrogen loss and profitability from mitigations for 43 drystock farms

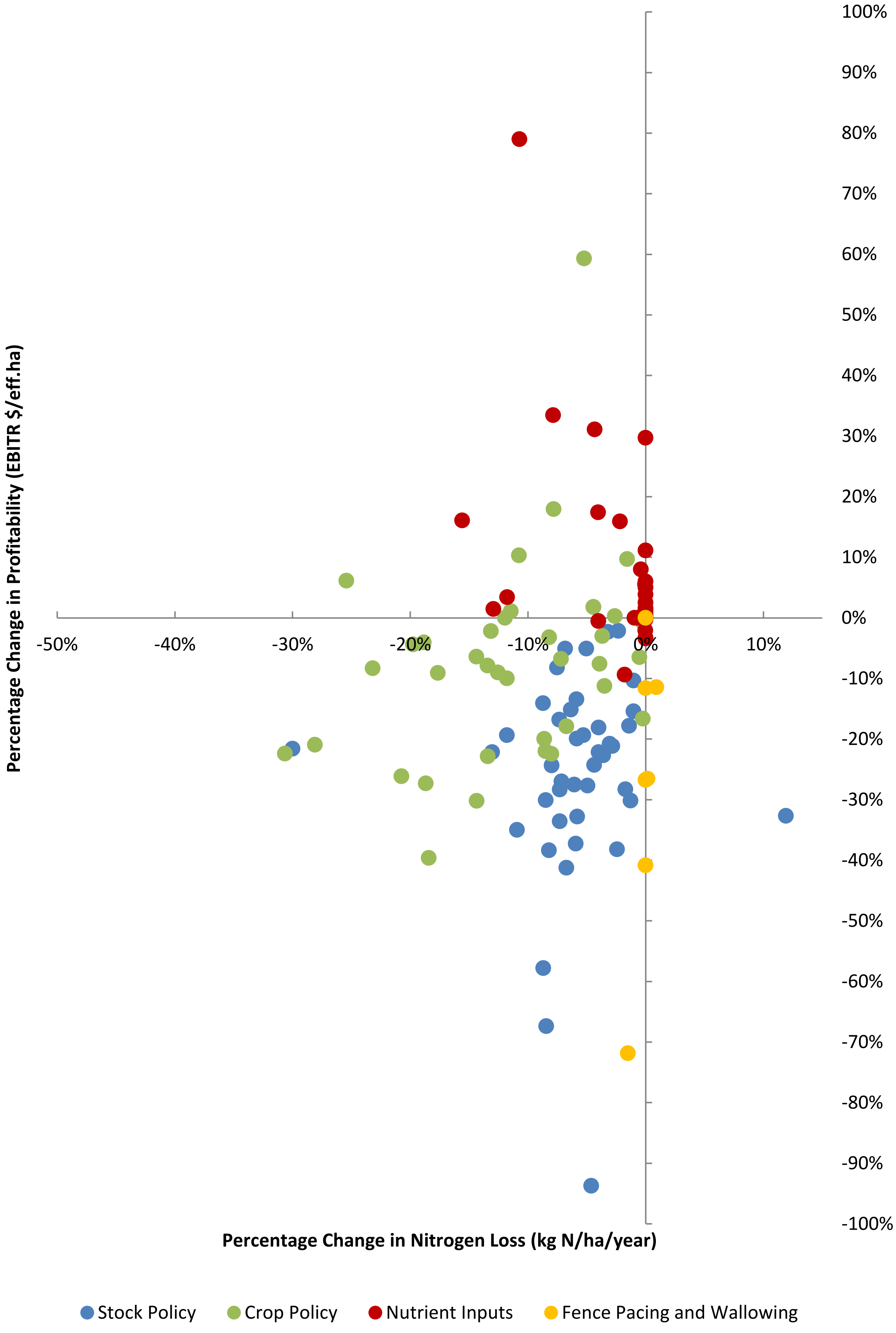

Figure C22: Percentage change in nitrogen loss and profitability from mitigations for 43 drystock farms

Nutrient Inputs Mitigation

The nutrient inputs mitigation was used on 32 of the 43 farms and had the least impact on profitability of the mitigations modelled, decreasing nitrogen loss while increasing profitability for most farms. The remaining 11 farms did not apply nitrogen to pasture on their farm in 2013-14 (the year modelled). On 16 of the 32 farms, the nutrient inputs mitigation did not achieve any reductions in nitrogen losses because they did not apply nitrogen – they had savings from reduced phosphorus fertilisers.

The largest reductions in nitrogen loss rates were for two deer farms, where nitrogen losses were reduced by 4-5 kg N/ha/year. Both of these farms were applying nitrogen (fertiliser) to pasture. The extent to which ongoing reduced nutrient inputs would be sustainable for farm profitability is unclear but for at least one farm this would likely only be a short-term measure. The remaining five deer farms showed no difference in nitrogen loss rates from the nutrient inputs mitigation.

Overall, 22 of the 32 farms showed some increase in profitability. However, increases that are as a result of buying less fertiliser may be temporary. If fertiliser use is below maintenance level then soil fertility will decrease and farm productivity is likely to decline – because of lower feed production and the need to either import more feed or reduce stock numbers. Of the remaining 10 farms, 4 farms had no change in profitability and 6 farms had a decline in profitability. Figure C23 shows the changes in nitrogen loss and profitability for the nutrient inputs mitigation.

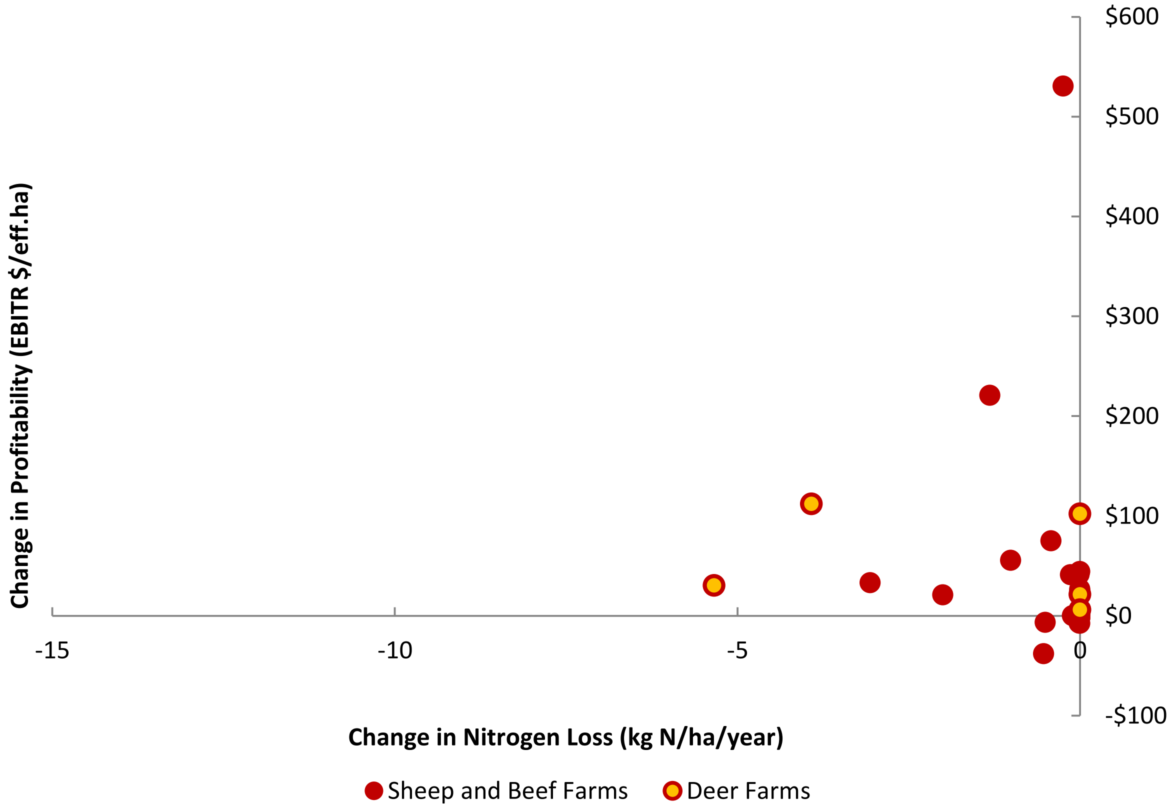

Figure C23: Change from nutrient inputs mitigation on nitrogen loss and profitability for 32 farms

Crop Policy Mitigation

The crop policy mitigation was used on 37 farms. It was the most effective in reducing nitrogen losses on most farms but had a negative impact on profitability (although not in all cases). This mitigation achieved an average reduction in nitrogen loss of 2 kg N/ha/year and median of 1 kg N/ha/year. It reduced nitrogen loss by the greatest absolute amount on farms with higher baseline nitrogen loss. The crop policy mitigation was not modelled for five farms with large absolute crop areas because the farming practices meant that the mitigation was too challenging to model successfully. Overall, this mitigation resulted in a decrease in profitability for the drystock farms but for eight of the 37 farms modelled, it increased profitability (five of the eight were deer farms).

Where the mitigation decreased in profitability it usually related to lower stock numbers, which affected production. Some farms could not replace the lost dry matter from the reduced crop area with increased made-on-farm supplements, and the only way for the farm to continue to be feasible was to reduce stock numbers. Where there was an increase in profitability it usually arose from a change to a higher yield crop e.g. fodder beet and lower costs from the reduced crop area, without affecting stock numbers. For example, the crop policy mitigation resulted in the selling off of stock (a one-off impact) on Farm 10 and Farm 29, but had contrasting impacts on profitability because of the complexity of farm systems and differences in baseline nutrient losses. For Farm 10 it increased profitability by $332 per effective hectare, but for Farm 29 it decreased profitability by $319 per effective hectare. Figure C24 shows the changes in nitrogen loss and profitability for the crop mitigation.

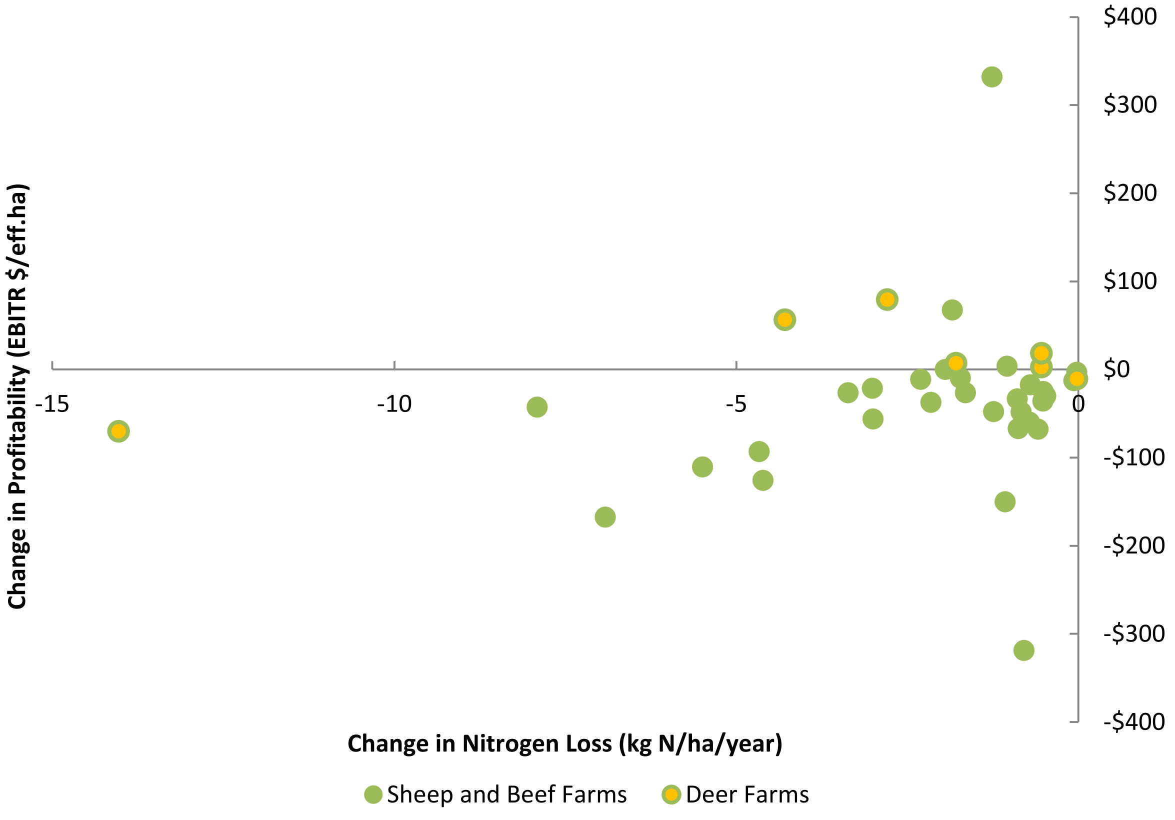

Figure C24: Change from crop policy mitigation on nitrogen loss and profitability for 37 farms

The results appear to show a positive relationship between the proportion of effective area in crop on a farm, and the reduction in nitrogen loss achieved through the cropping mitigation (although there were some outliers). In other words, the more of a farm's effective area in crop, the more effective the mitigation was in reducing nitrogen losses. A reason is the winter cropping areas are often 'hotspots' for nitrogen loss and the larger the area, the greater the loss. Figure C25 shows the relationship between effective area in crop, and percentage nitrogen loss reduced through the crop mitigation.

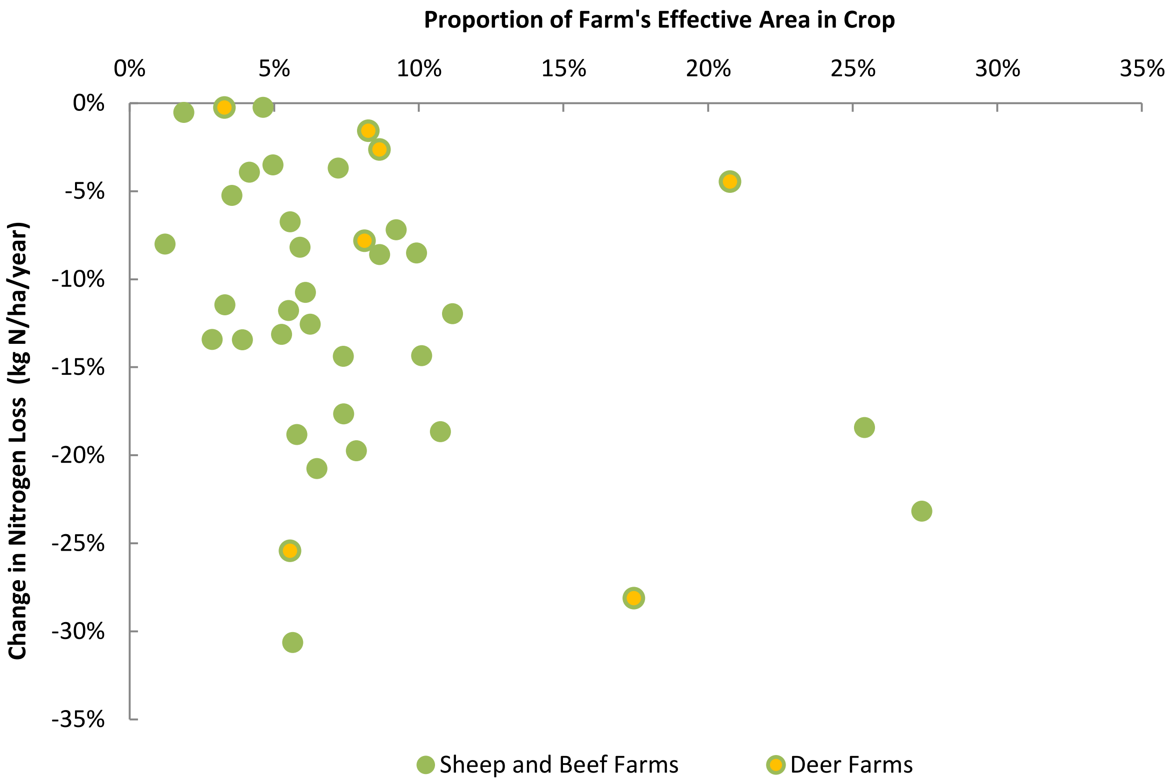

Figure C25: Relationship between change in nitrogen loss from crop policy mitigation for nitrogen loss and proportion of effective area in crop

Stock Policy Mitigation

The stock policy mitigation was applied to all 43 farms modelled and was the least effective and highest impact on profitability of the mitigations modelled because it directly impacted production. This mitigation reduced nitrogen losses by 1 kg N/ha/year or less on 31 farms, by 1-5 kg N/ha/year on 10 farms, and by 10 kg N/ha/year or more on one farm. It increased nitrogen losses by 1-5 kg N/ha/year on one farm (Farm 18) – this result as an example of a 'bug' in OVERSEER that was unable to be rectified.

The stock policy mitigation reduced nitrogen loss by the greatest amount on farms with higher baseline nitrogen loss. Reductions in profitability are large in comparison to the nitrogen loss reductions. Reducing stock on drystock farms decreased farm profitability for two main reasons. First, there is a strong relationship between stock numbers and profitability because, in terms of meat production at least, a farm's livestock are its product. Second, there were few savings in imported feed from lower stock numbers because most drystock farmers spend a very small amount on imported feed in the first place, generally farming to the carrying capacity of the land. Figure C26 shows the change in nitrogen loss and profitability for the stocking rate mitigation.

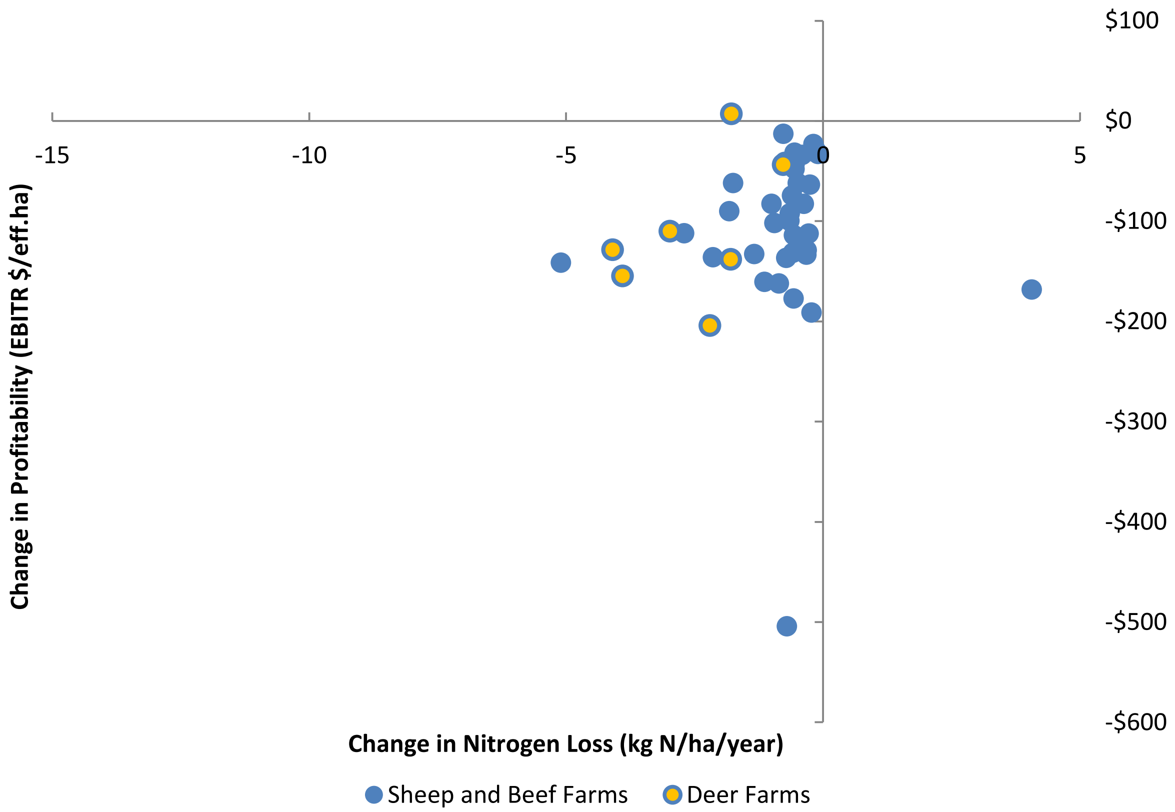

Figure C26: Change from stock policy mitigation on nitrogen loss and profitability for 43 farms

Fence Pacing and Wallowing Mitigation

The fence pacing and wallowing mitigation was used for six of the seven deer farms. This mitigation was not used for Farm 44 or the four sheep and beef farms with deer because these farms had already achieved these good management practices (GMP). The mitigation was unsuccessful in reducing nitrogen loss in OVERSEER; nitrogen losses either remained the same or slightly increased. This result is unsurprising as the effect of fence pacing is to create pathways of bare ground that channel soil and droppings during rain events. These nutrient losses will then flow into a water body if it is connected to the paddock. Nitrogen loss through urine, fertiliser application or mineralisation is unlikely to be affected by channelling of soil during rain. It did have an impact on profitability as deer fencing is relatively expensive, and the cost increases when the topography changes from flat to hill country.

Figure C27 shows the change in nitrogen loss and profitability for the seven deer farms for the fence pacing and wallowing mitigation. In the case of wallowing there is potential to reduce nitrogen as dung and urine may collect in wallows. However, this mitigation was only used for 10% of a farm's unfenced waterways a farm area so it is possible that the nitrogen loss reduction through mitigating wallowing is not significant compared with the normal nitrogen loss pathways occurring in the remaining 90% of the farm area.

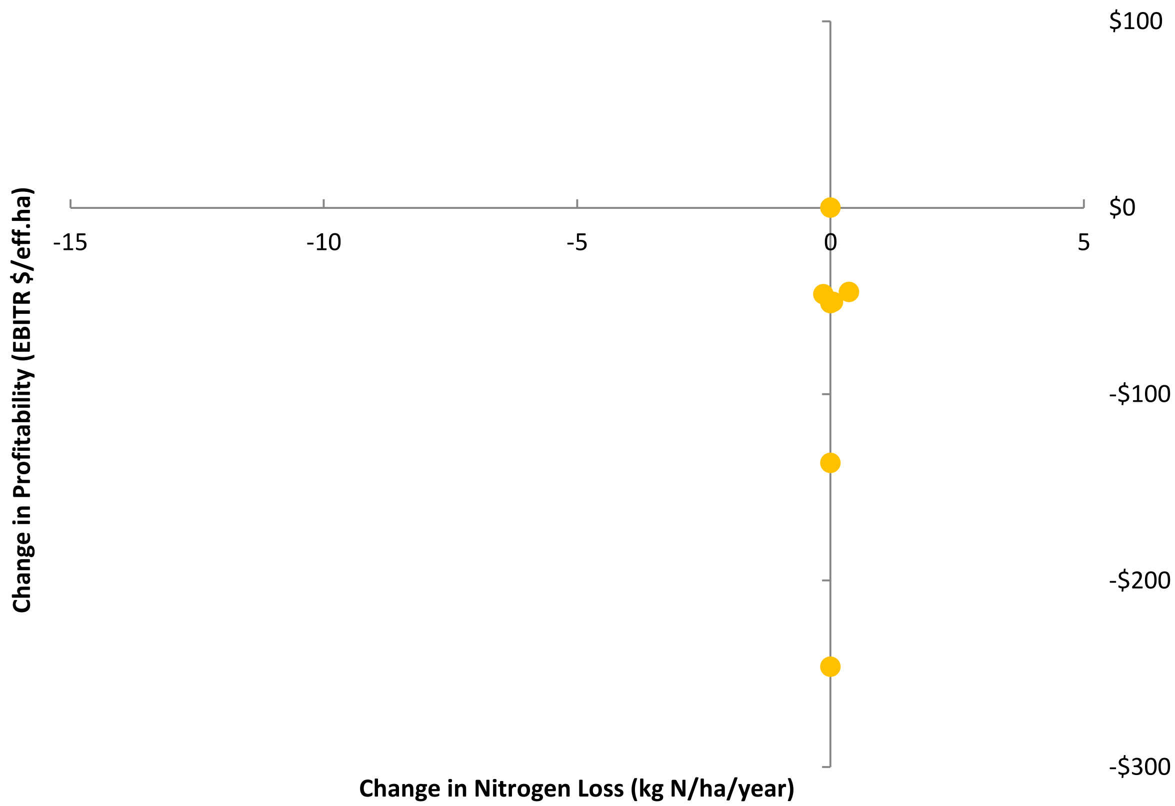

Figure C27: Change from fence pacing and wallowing mitigation on nitrogen loss and profitability for 6 farms

Based on the results for these six deer farms, mitigating fence pacing and wallowing would not reduce nitrogen loss rates but is likely to reduce profitability (i.e. additional costs are incurred with no benefit for nitrogen loss). However, it is expected that other benefits will result – particularly for reductions in the loss rates of sediment, phosphorus and microbes.

Sheep and Beef

The range in results mean that for any particular farm the mitigations varied in the changes in nitrogen loss and profitability. Consequently, it is difficult to predict the combined effect of using more than one mitigation at a time – for example, putting the nutrient inputs together with crop policy. Figure C28 shows the results for the sheep and beef farms modelled with all three of the mitigations relevant to sheep and beef farming. Each farm's start point is shown as a blank (or clear) dot. The amount and direction of change from the three mitigations is shown as the coloured dots (red, green and blue). Some of the data points on the graph overlap either because there was not a marked change in a farm's nutrient loss or profitability or because one farm's results intersect with those of another farm. An OVERSEER 'bug' is evident in the results for Farm 18 that shows applying the stock policy mitigation increased the farm's nitrogen losses.

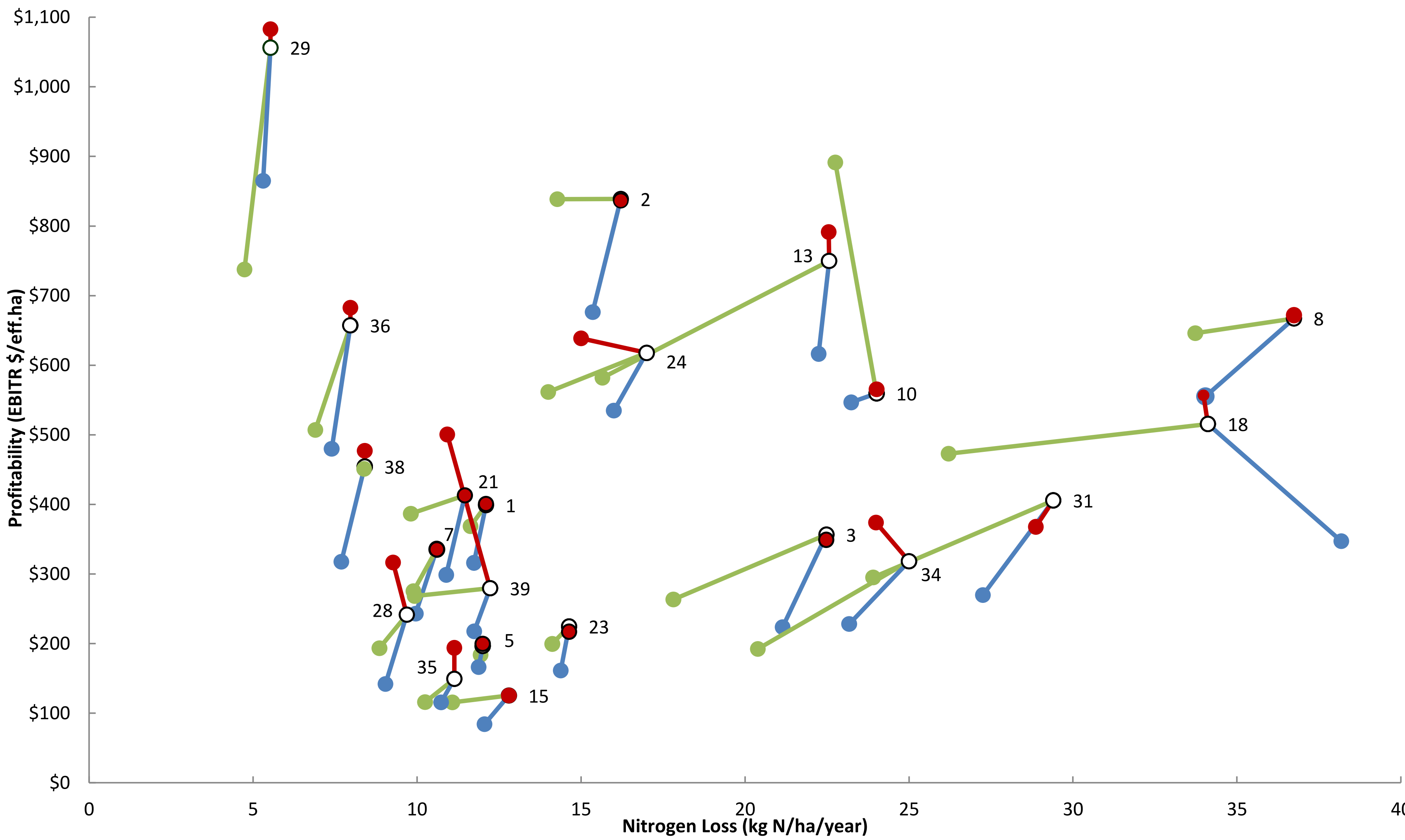

Figure C28: Amount and direction of change from nutrient inputs, crop policy and stock policy mitigations for 21 sheep and beef farms with all 3 mitigations
Key: clear dot, black outline = baseline result; red dot/line = nutrient Input mitigation; green dot/line = crop policy mitigation; blue dot/line = stock policy mitigation

Deer

The results suggest that the seven deer farms appear to have limited ability to reduce nitrogen losses. Altering a farm's nutrient inputs reduced nitrogen loss rates of more than 1 kg N/ha/year on one farm but improved profitability, possibly just in the short-term, for some farms. Reducing stock numbers resulted in reductions across all seven farms from 1 to 4 kg N/ha/year (4-13%). This mitigation decreased profitability by an average of 33% and a median of 35%. The crop policy lead to reductions of between 1 and 4 kg N/ha/year (2-25%) on five farms, no change for one farm and a reduction of 14 kg (28%) for the last farm. This mitigation had quite variable impacts on profitability.

Overall, the mitigations either resulted in changes in nitrogen loss rates of between 0 and 4 kg N/ha/year, except for the crop mitigation which reduced nitrogen loss rates by 14 kg on one farm (Farm 42) but decreased its profitability by 21%. Figure C29 shows the effects of the mitigations modelled on nitrogen loss and profitability for each of the seven deer farms. The fence pacing and wallowing mitigation was not applied to Farm 40 because it was considered to already be at good management practice.

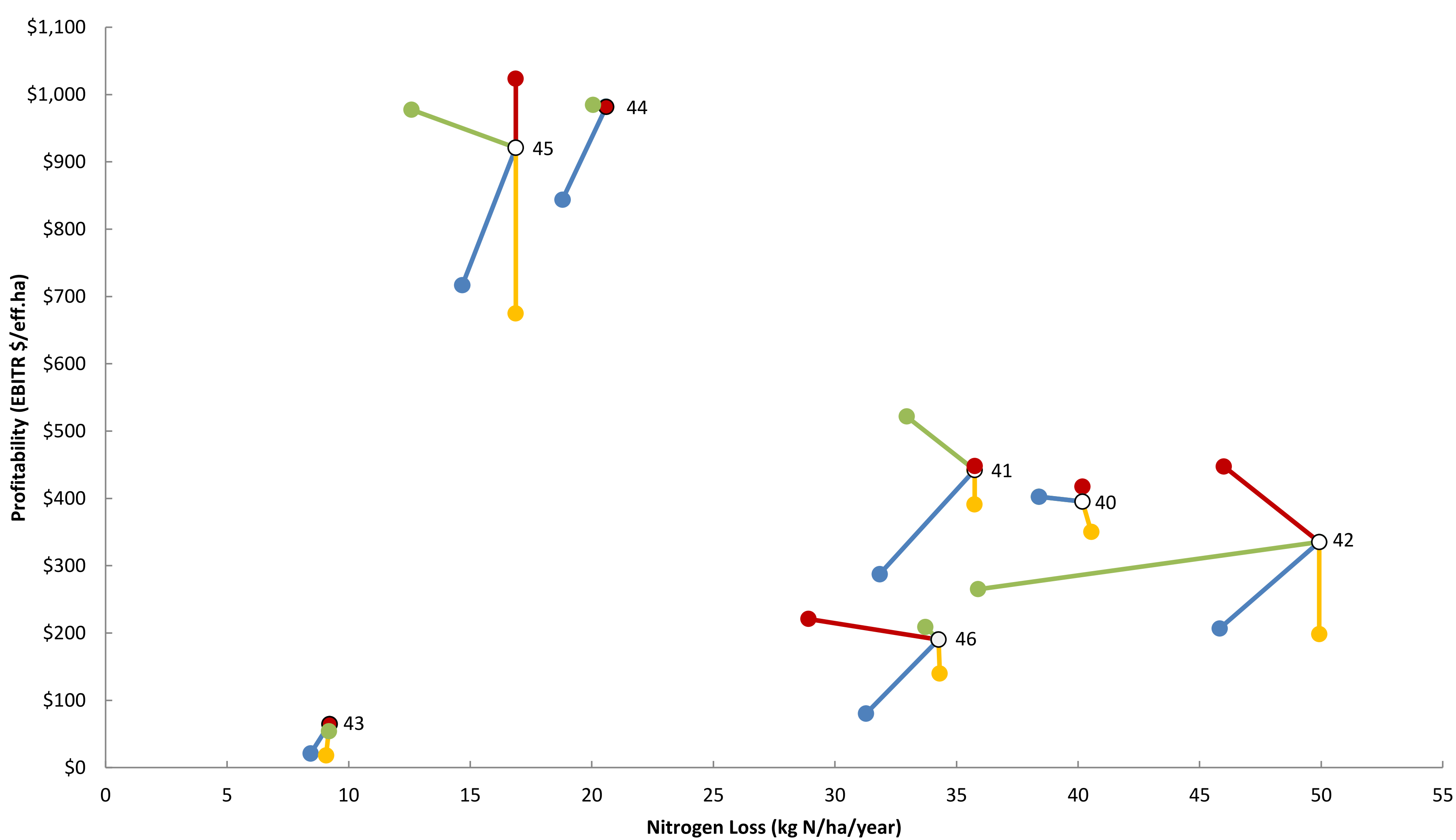

Figure C29: Direction of change from mitigations for seven deer farms
Key: clear dot, black outline = baseline result; red dot/line = nutrient Input mitigation; green dot/line = crop policy mitigation; blue dot/line = stock policy mitigation; yellow dot/line = fence pacing and wallowing mitigation

2.6.2. Phosphorus

Table C16 gives the number of farms modelled with each of the mitigations and the distribution of phosphorus loss results. Most mitigations usually either decreased or had no effect (0 kg column) on a farm's phosphorus loss. Although the crop mitigation slightly increased phosphorus losses for 12 of the 37 farms on which the mitigation was applied. They tended to have more effect on some of the smaller farms because these farms had higher baseline losses.

Table C16: Number of farms with each mitigation and change in Phosphorus Loss (kg P/kg/year)

Mitigations	Number of Farms	+1 to 0 kg	0 kg	0 to -0.05kg	-0.05 to -0.1 kg	-0.1 to -0.2 kg	-0.2 to -0.3 kg
All farms <1,000 eff.ha							
Nutrient Input	**24**	1	3	16	2	2	-
Crop Policy	**32**	12	1	-	19	-	-
Stock Policy	**33**	2	3	28	-	-	-
Fence Pacing	**5**	-	-	-	1	1	3
All farms >1,000 eff. ha							
Nutrient Input	**8**	1	1	5	1	-	-
Crop Policy	**5**	-		5	-	-	-
Stock Policy	**10**	-	1	9	-	-	-
Fence Pacing	**1**	-	-	-	-	-	1
Total							
Nutrient Input	**32**	2	4	21	3	2	-
Crop Policy	**37**	12	1	5	19	-	-
Stock Policy	**43**	2	4	37	-	-	-
Fence Pacing	**6**	-	-	-	1	1	4

The mitigation results for the 43 drystock farms showed that mitigations were generally ineffective in reducing phosphorus losses, except for the fence pacing and wallowing mitigation on the deer farms.

The relationship between a farm's 'start point' (or baseline phosphorus loss) and the effectiveness of a mitigation (the change in phosphorus loss) depended on the mitigation. In other words, the results showed different relationships between a farm's baseline phosphorus loss and and the amount of change from a mitigation.

The fence pacing and wallowing mitigation tended to be more effective if a farm started with higher baseline phosphorus. A farm's baseline tended to not make much of a difference for the effectiveness of the nutrient inputs, crop policy, and stock policy mitigations, although the crop policy appeared to be slightly less effective if a farm had higher baseline phosphorus losses to begin with.

Figure C30 shows the farm start points and the change in phosphorus losses from the four mitigations – the mitigation results are plotted by a farm's baseline phosphorus loss (x-axis) and its change in phosphorus loss from each mitigation (y-axis). Overall, the distribution of the data points (from left to right) suggests a downward slope for the fence pacing and wallowing mitigation, and is roughly level for the nutrient inputs, crop policy, and stock policy mitigations.

The crop policy and the stock policy mitigations were fairly ineffective in mitigating phosphorus losses from the farms modelled.

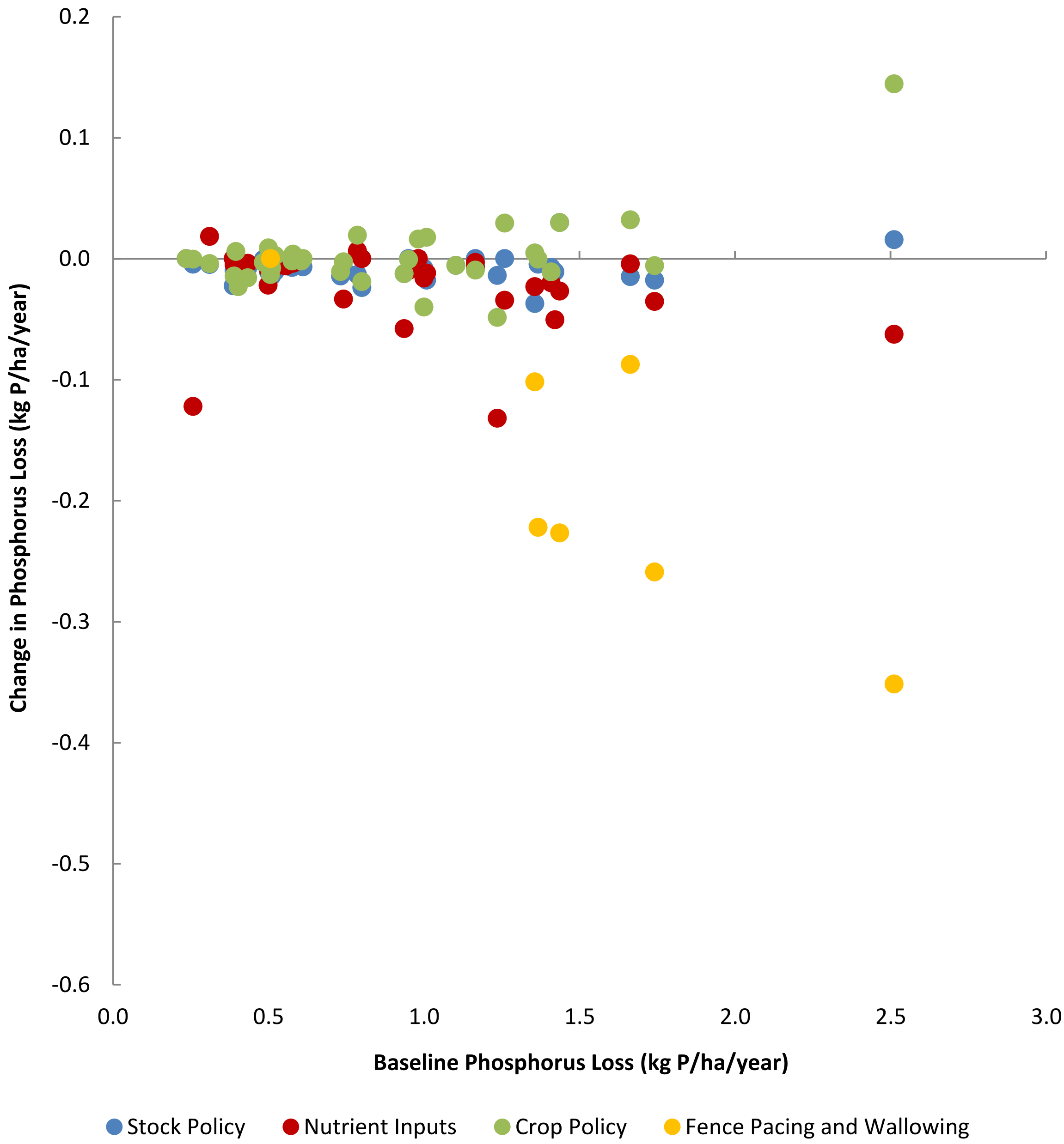

Figure C30: Relationship between baseline phosphorus loss and change in phosphorus loss for 43 drystock farms

The results showed different relationships between a farm's 'start point' (or baseline phosphorus losses) and the change in profitability from a mitigation. In this case, the relationships between the baseline and the impact on profitability were negative for all of the mitigations except fence pacing and wallowing. The negative impacts on profitability of the nutrient inputs, crop policy and stock policy mitigations tended to be less if a farm had higher baseline phosphorus losses. In contrast, the impacts of the fence pacing and wallowing mitigation tended to be more if a farm had higher baseline losses. It is likely that this result is because both the baseline phosphorus losses and the costs of the fence pacing and wallowing mitigation are related to the length of a farm's waterways.

Figure C31 shows the baseline phosphorus losses and the change in profitability from the four mitigations – the mitigation results are plotted by a farm's baseline phosphorus loss (x-axis) and its change in profitability following each mitigation (y-axis). In general, the distribution of the data points is upward sloping from left (lower baseline phosphorus losses) to right (higher baseline phosphorus losses) – except for the fence pacing and wallowing mitigation, which is downward sloping.

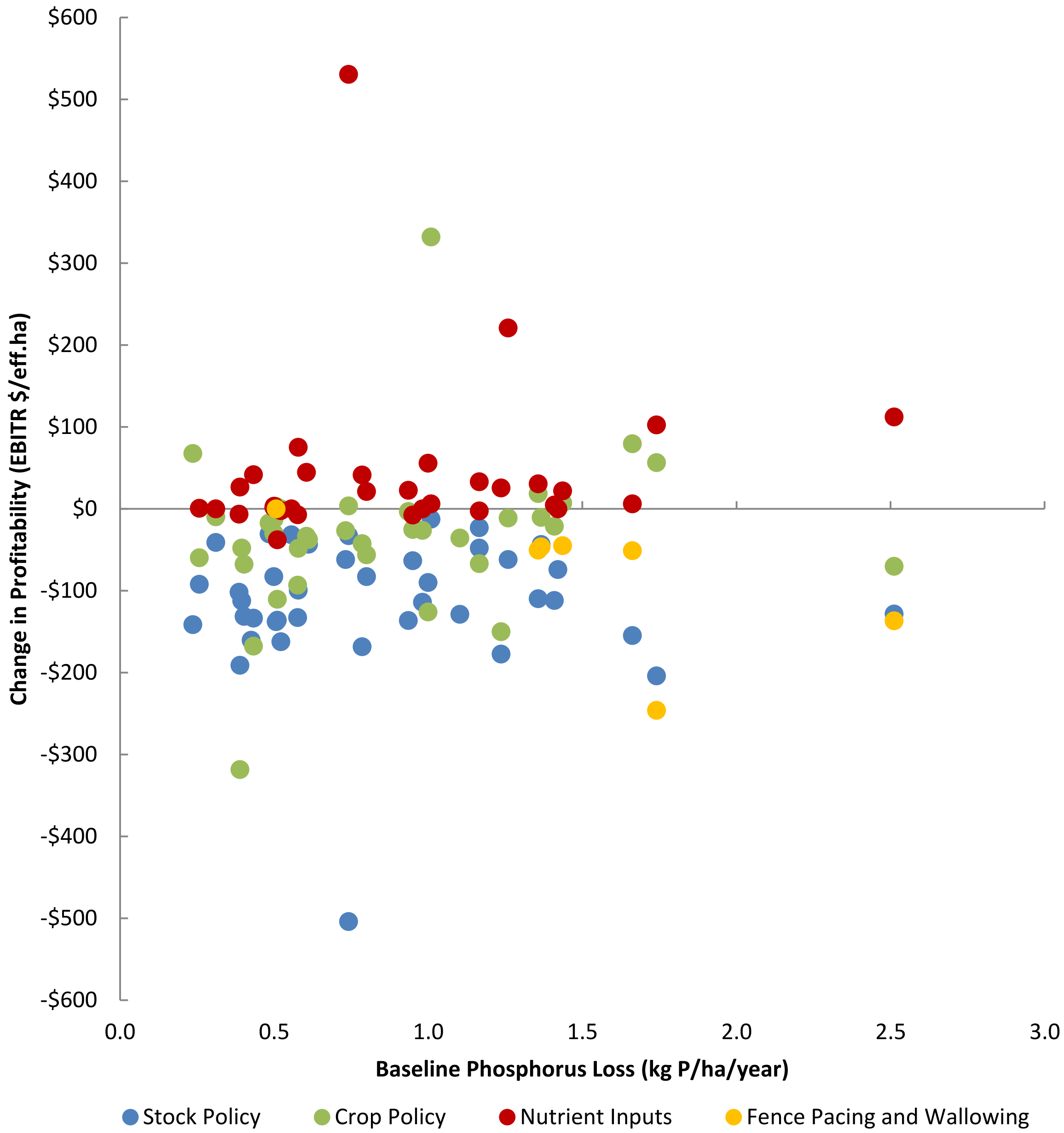

Figure C31: Relationship between baseline phosphorus loss and change in profitability for 43 drystock farms

When these two graphs are considered together, they suggest that the mitigations' negative impacts on profitability appear to be less for the farms with higher baseline losses but their effectiveness in relation to baseline losses was mixed. The exception was the fence pacing and wallowing mitigation, where the opposite was the case.

Similar to the results for nitrogen, the mitigations had varying effects on phosphorus loss and profitability. The costs of the mitigations are discussed in Part C, Section 2.4.3 Nutrient Loss and Profitability. Figure C32 shows the changes in phosphorus loss and profitability for each mitigation – the distance each data point is from '0' is the amount of change in a farm's phosphorus losses and profitability from its baseline. Figure C33 shows the same changes in phosphorus loss and profitability <u>as a percentage</u> from a farm's baseline.

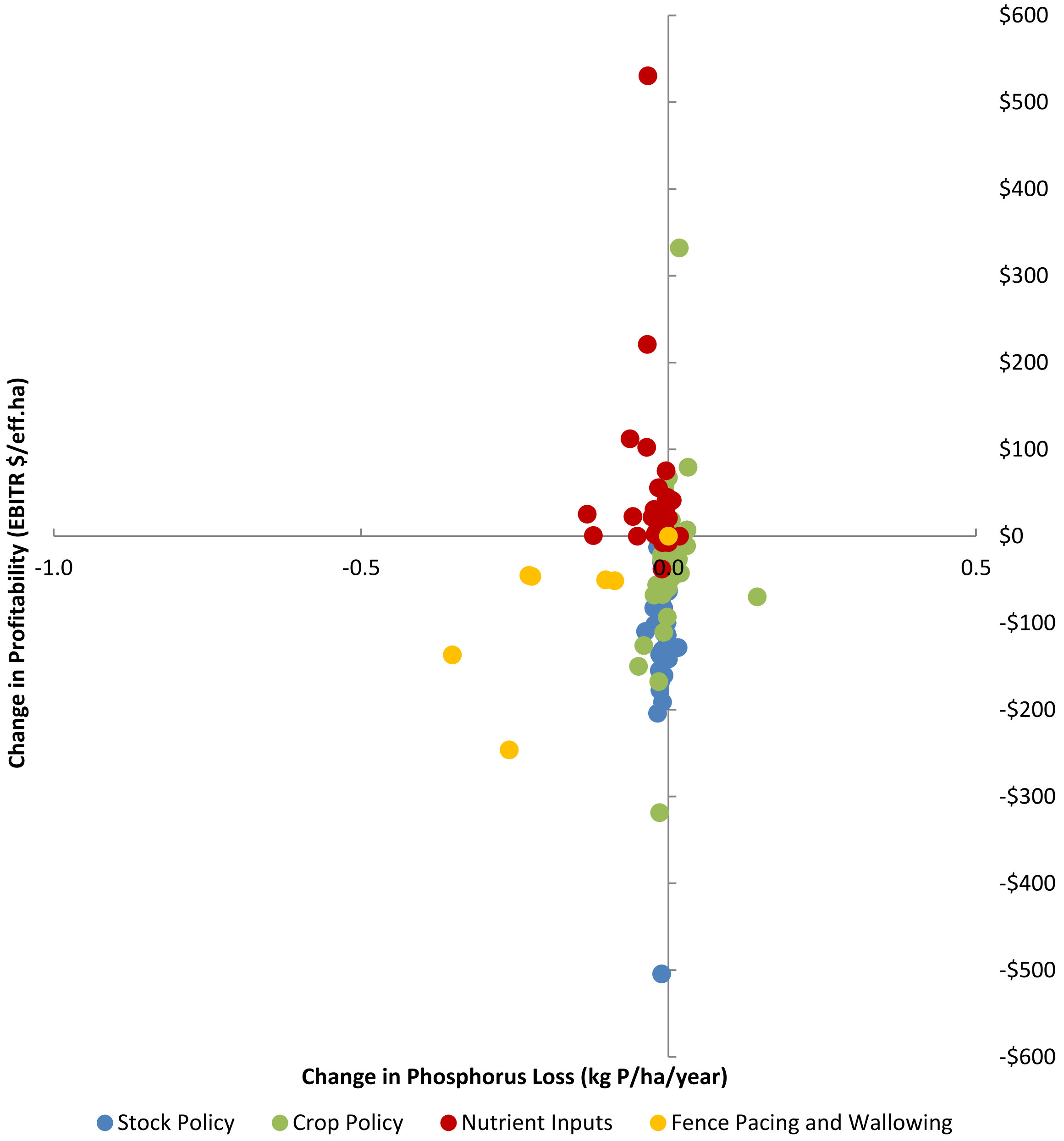

Figure C32: Change in phosphorus loss and profitability from mitigations for 43 drystock farms

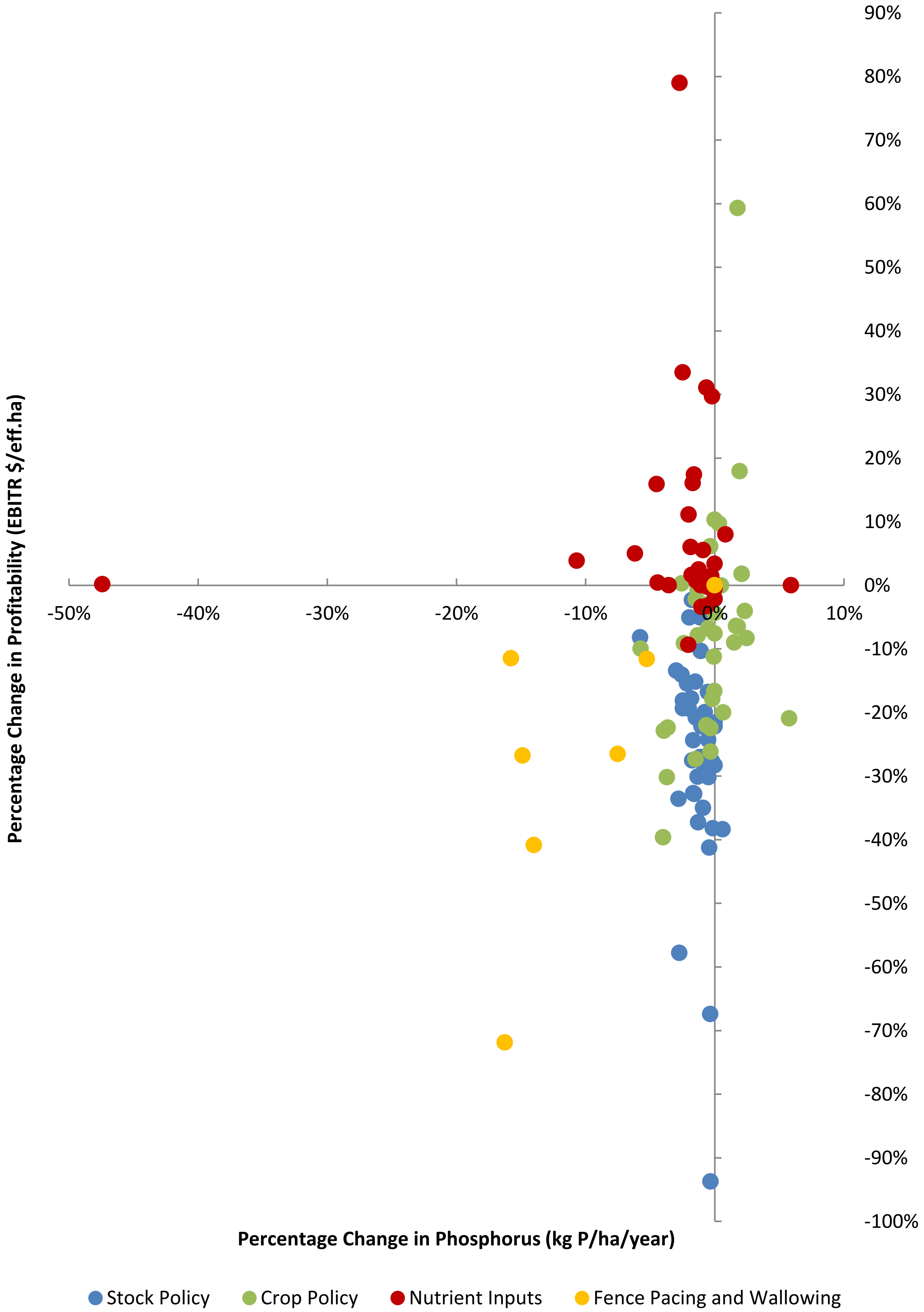

Figure C33: Percentage change in phosphorus loss and profitability from mitigations for 43 Drystock Farms

Nutrient Inputs Mitigation

Similar to the nitrogen results, the nutrient inputs mitigation achieved small reductions in phosphorus losses and increased farm profitability. The phosphorus loss reductions were less than 0.1 kg P/ha/year on 20 farms and just over 0.1 kg P/ha/year on two farms. This mitigation achieved a 47% reduction in phosphorus on one farm (Farm 7). This farm had a relatively large ineffective area and low phosphorus losses - capital applications of fertiliser were being used on parts of the farm to increase the soil's Olsen P levels and when these applications were reduced to maintenance fertiliser it halved the farm's phosphorus losses. The mitigation did not change the phosphorus loss on the remaining farms. Figure C34 shows the changes in phosphorus loss and profitability for the nutrient inputs mitigation.

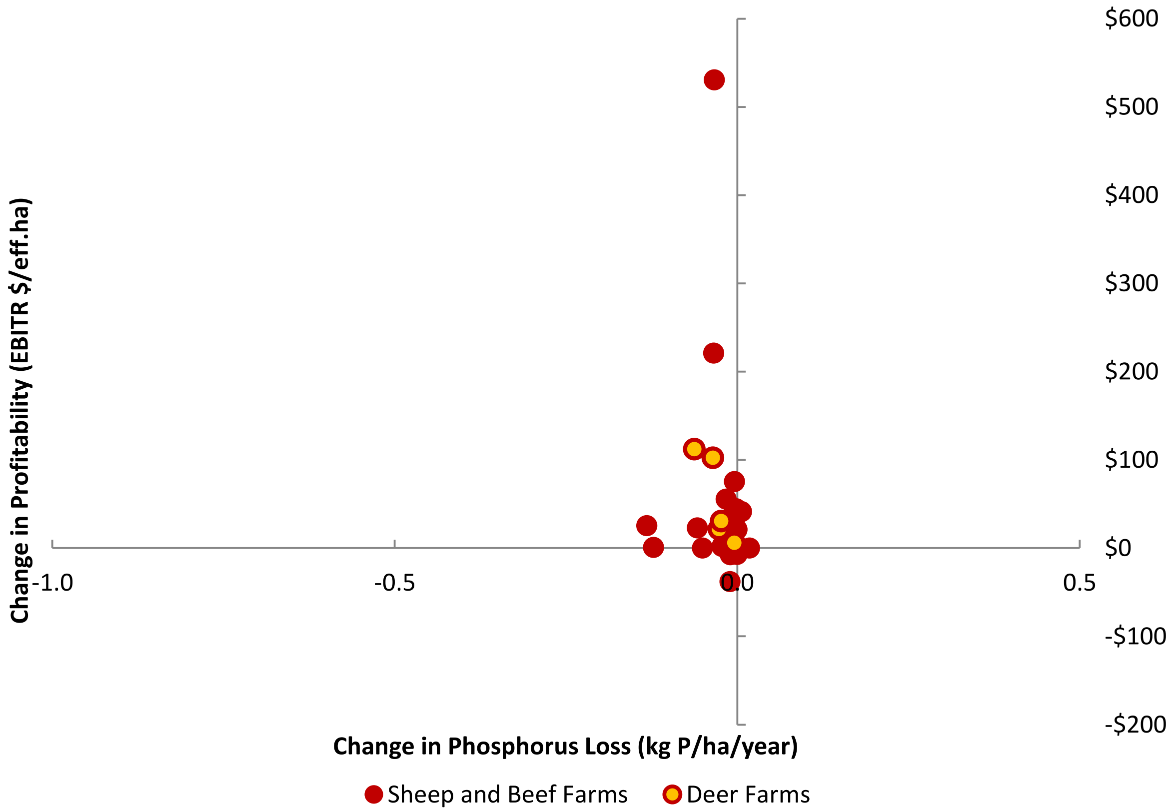

Figure C34: Change from nutrient inputs mitigation on phosphorus loss and profitability for 32 farms

Crop Policy Mitigation

Although the crop policy mitigation was relatively effective in reducing nitrogen loss it had little effect on phosphorus loss for the 43 drystock farms. For most farms, phosphorus losses did not respond to this mitigation, with a reduction of less than 0.1 kg P/ha/year, no change, or an increase. Phosphorus loss was reduced by just over 0.1 kg P/ha/year on one farm only (Farm 42). Currently the phosphorus loss effect on crop blocks is not built into OVERSEER which is only slightly responsive to a handful of management settings and most mitigation options will not change phosphorus losses. Consequently, modelling a change in crop policy has more impact on nitrogen (affecting nitrogen mineralisation in the soil or increased urine from grazing of animals on the crop) than phosphorus as modelled in OVERSEER. Figure C35 shows the changes in phosphorus loss and profitability for the crop policy mitigation.

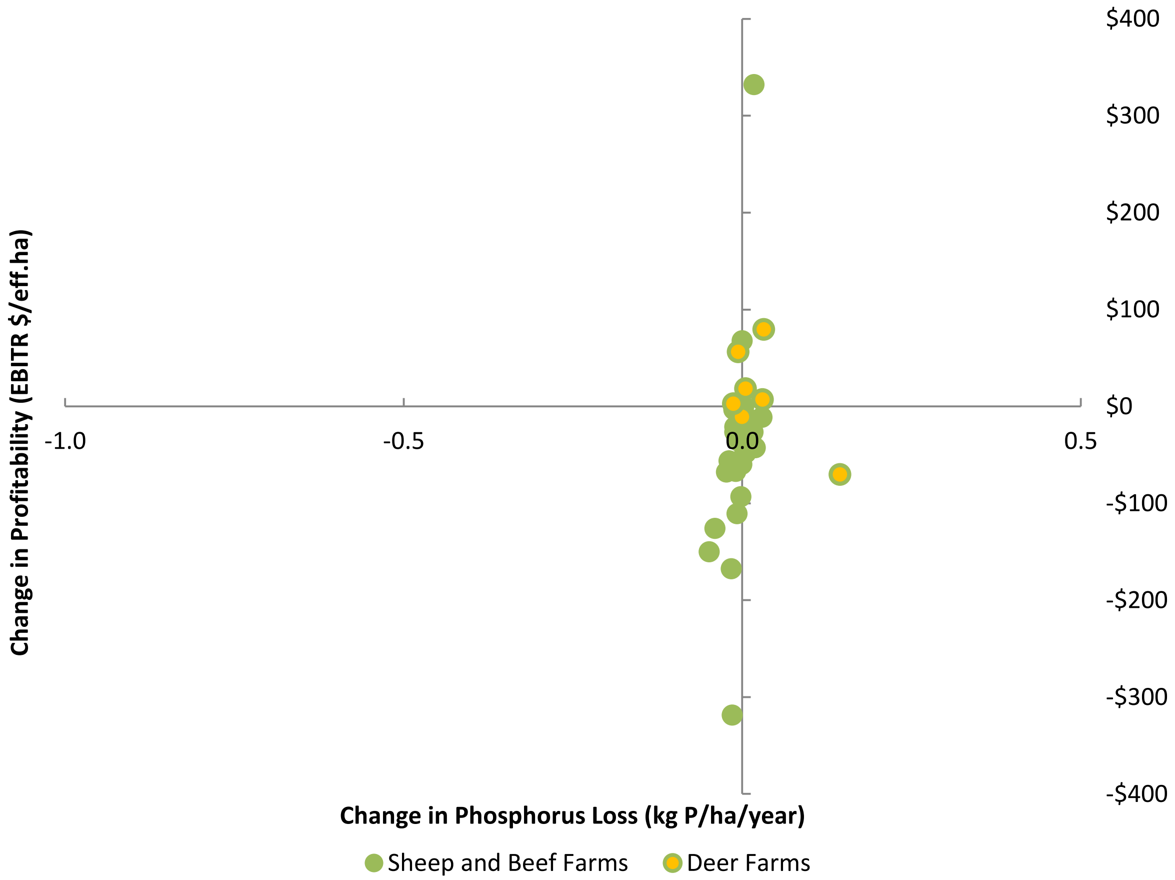

Figure C35: Change from crop policy mitigation on phosphorus loss and profitability for 37 farms

Stock Policy Mitigation

The results for the stock policy mitigation for phosphorus were quite consistent across the 43 drystock farms: the mitigation achieved little or no reduction in phosphorus loss on most farms and, as discussed above, it had large impacts on farm profitability. Figure C36 shows the changes in phosphorus loss and profitability for the stock policy mitigation.

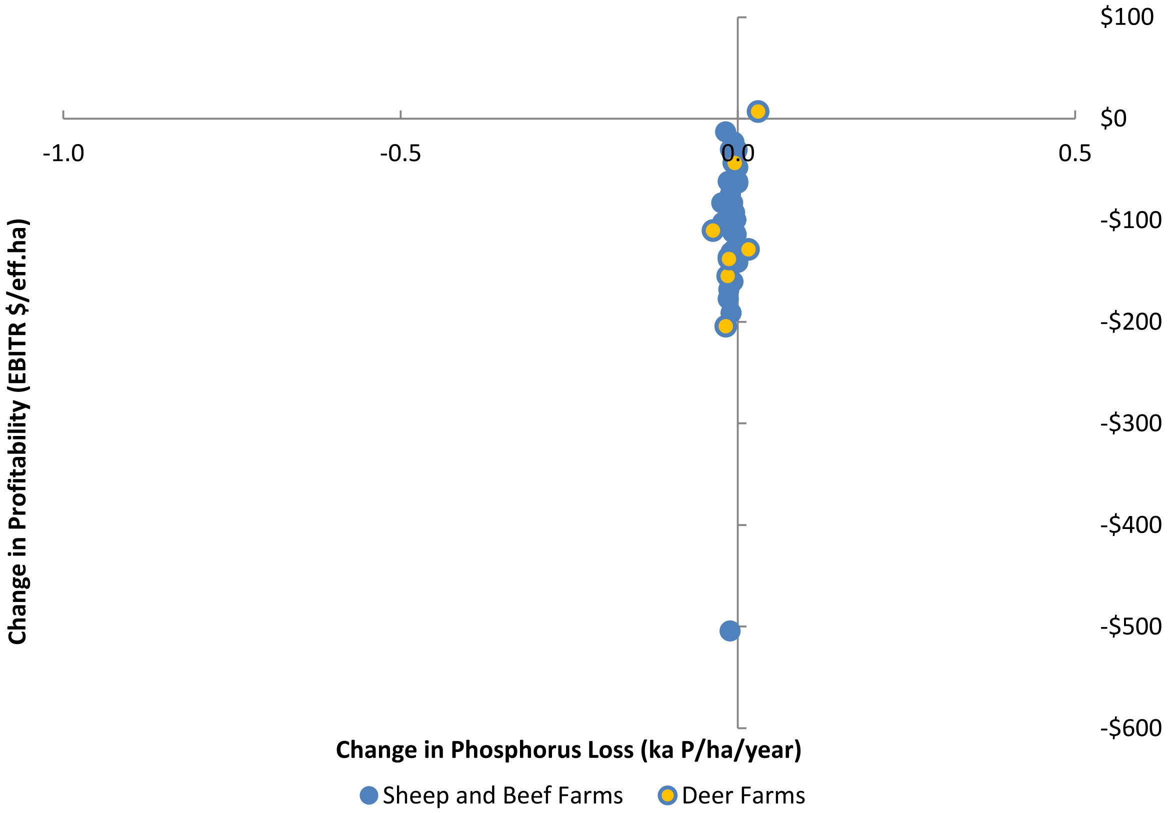

Figure C36: Change from stock policy mitigation on phosphorus loss and profitability for 43 farms

Fence Pacing and Wallowing Mitigation

The fence pacing and wallowing mitigation was more successful at reducing phosphorus than nitrogen, which was expected. The fence pacing and wallowing mitigation was applied to six of the seven deer farms. Across these farms there was a wide range of phosphorus loss reductions, from 0% for one farm to around 15% for four farms. In absolute terms, the average and median phosphorus reduction was 0.2 kg P/ha/year. While this mitigation was more successful in achieving reductions in phosphorus than the other mitigations modelled, it decreased farm profitability by an average of $82 per effective hectare (-27%) with a median of $50 per effective hectare.

The approach to estimating phosphorus losses in OVERSEER does not fully reflect the range of loss pathways on-farm (Gray, Wheeler, McDowell, & Watkins, 2016). In particular for hill county drystock farming, critical source areas are not well estimated and nor are unpredictable episodic events (storms, prolonged or intense rainfall) that cause mass earth movement (earthflows or landslides).

Similarly, OVERSEER only requires the user to specify fence pacing and wallowing as either present or absent, whereas in reality, fence pacing can be greatly reduced or eliminated through good stock management while wallowing may require more expensive remediation or active management to move stock to different paddocks if signs of wallowing commence (Lindsay Fung, pers. comm. 2017 – refer to Part B, Section 3.9). There will possibly be some changes in costs but it is more about providing adequate feed, reducing stress on stock and not shifting stock between paddocks too often. Figure C37 shows the changes in phosphorus loss and profitability for the fence pacing mitigation.

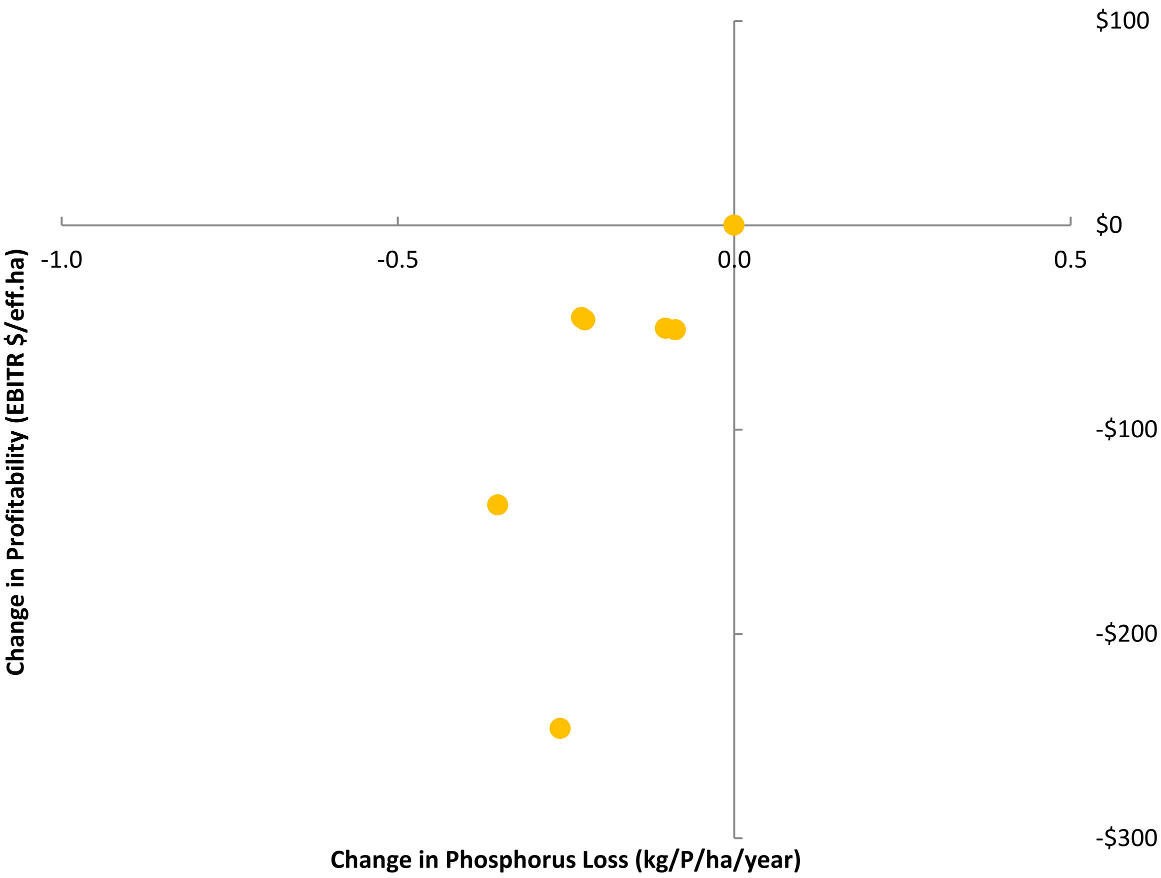

Figure C37: Change from fence pacing and wallowing mitigation on phosphorus loss and profitability for 6 deer farms

Sheep and Beef

The range in mitigation results mean that for any particular farm the mitigations varied in the changes in phosphorus loss and profitability. Figure C38 shows the results for the sheep and beef farms that were modelled with all three of the mitigations relevant to sheep and beef farming (i.e. the first three mitigations). By comparison with Figure C28 (above), the results show the mitigations had a considerably greater impact of farm profitability than phosphorus loss.

Deer

The seven deer farms appear to have more ability to reduce phosphorus losses than nitrogen losses, through mitigating fence pacing and wallowing. However, this mitigation comes at a considerable cost in terms of reductions in farm profitability. The impacts of the fence pacing and wallowing mitigation, which was applied to 10% of the unfenced waterways, decreased profitability by an average and a median of 27%. The other mitigation options (nutrient inputs, crop policy and stock policy) achieved minimal or no reductions in phosphorus loss. Figure C39 shows the effects of the mitigations modelled on phosphorus loss and profitability for each of the seven deer farms.

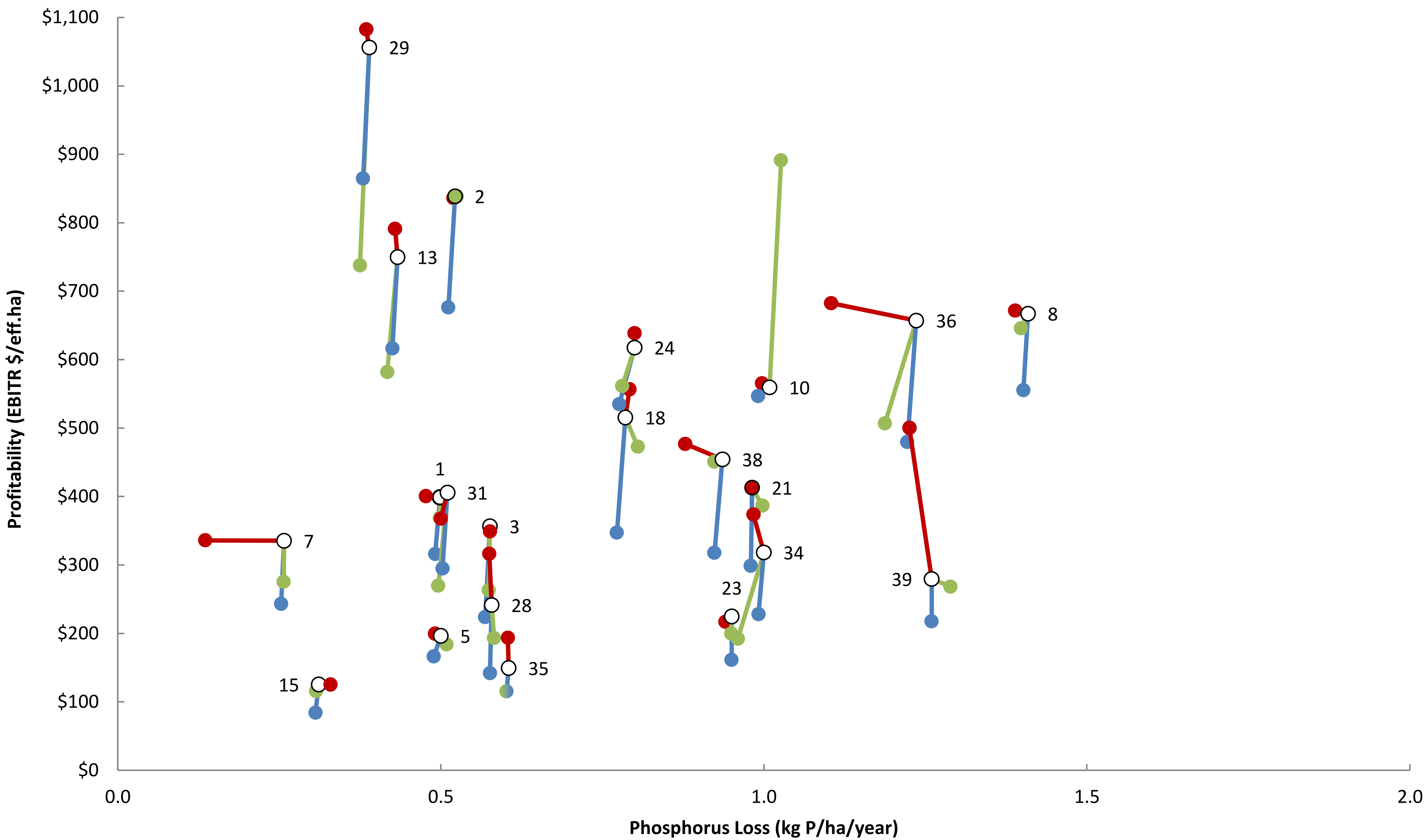

Figure C38: Amount and direction of change from nutrient inputs, crop policy and stock policy mitigations for 21 sheep and beef farms with all 3 mitigations

Key: clear dot, black outline = baseline result; red dot/line = nutrient Input mitigation; green dot/line = crop policy mitigation; blue dot/line = stock policy mitigation

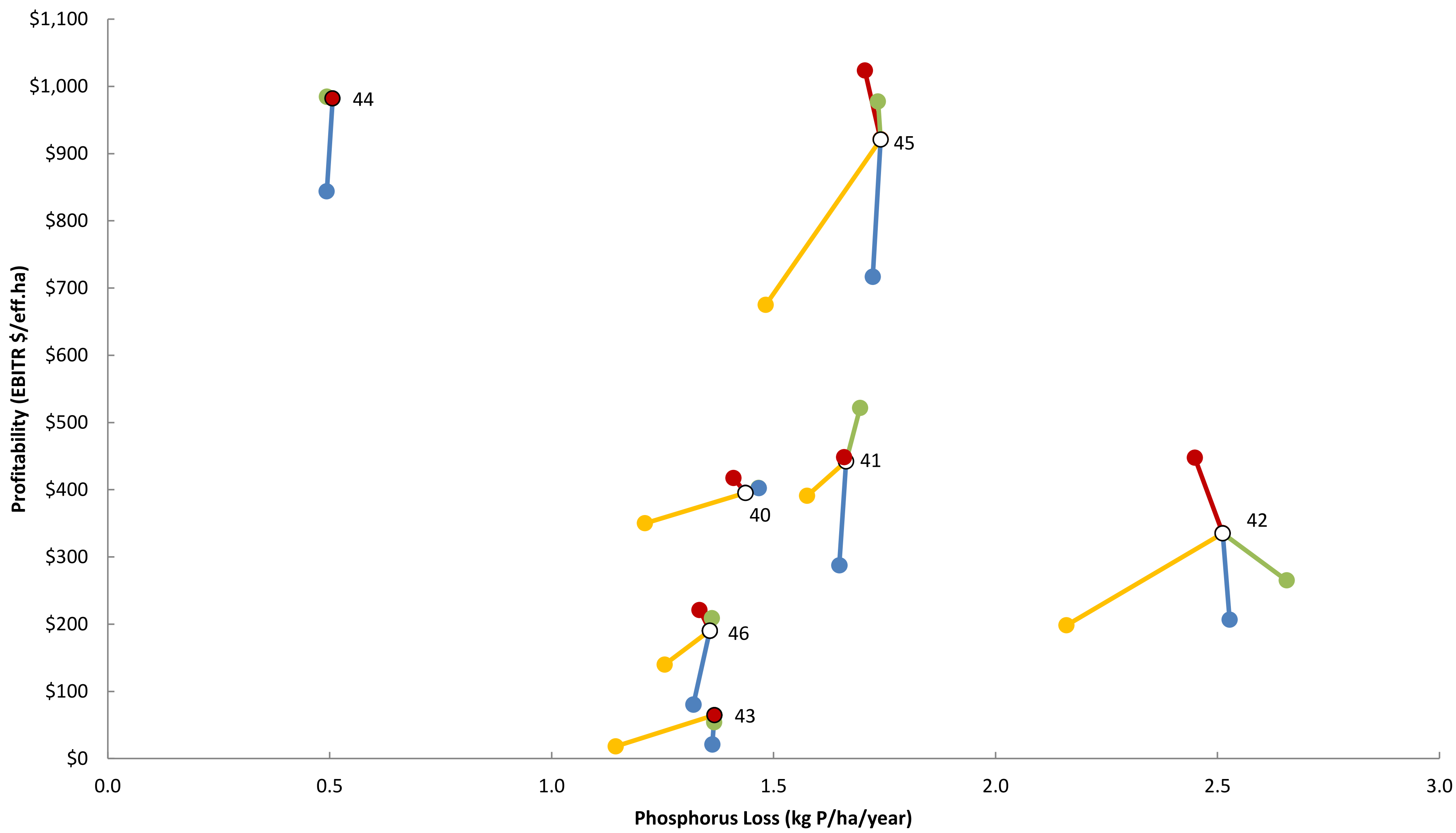

Figure C39: Direction of change from mitigations for seven deer farms
Key: clear dot, black outline = baseline result; red dot/line = nutrient Input mitigation; green dot/line = crop policy mitigation; blue dot/line = stock policy mitigation; yellow dot/line = fence pacing and wallowing mitigation

2.6.3. Understanding Drivers of Farmer Decisions

Drystock farming is primarily a commercial business operation yet farmer decision-making is not always based purely on economic factors. Understanding what influences farmer decisions is helpful when considering how farmers may respond to environmental issues, particularly around the use of mitigations. Research done for the Red Meat Profit Partnership Ltd. has categorised farmers into five groups, depending on their acceptance of change, degree of planning and purpose. Family and way of life were identified as key drivers of performance in the sector in addition to profitability.

In addition to these key drivers, the integrated nature of farming can also influence farmer decision-making. For example, a mitigation that reduces stocking levels of one species would require reconsidering how available feed would be used. Drystock farmers use different types of livestock to help enhance pasture production and quality – where stock are used to control weeds such as ragwort, clean up roughage or excess feed in paddocks, and provide clean pastures to manage intestinal parasite and facial eczema problems. Although farmers change their mix of stock in response to different price signals for their various products, this mitigation could constrain decision-making and reduce a farm's flexibility, which could impact on profitability.

More fundamental decisions on farm management may also be influenced by the type of ownership. Traditionally, New Zealand farm ownership is based around a family with inter-generational succession. More recently this model has been declining as farming costs rise and there is a need to gain greater scale that is more suited to other ownership structures. Nevertheless, family-owned farming is still a dominant model for drystock farming and where it occurs farmers have the opportunity to take advantage of existing knowledge in the management of a farm, such as climatic conditions and the suitability of stock class/types to different farm blocks. This knowledge is invaluable in drystock farming because, with relatively infrequent monitoring of production and irregular income, there is limited ability to modify production systems throughout the year once decisions are made. Table C17 shows the proportion of single owners in the ownership structure of sheep and beef farms in New Zealand (farm classes relevant in Southland are highlighted in green).

Table C17: Ownership Structure of Sheep and Beef Farms in New Zealand – 2013-14 Weighted Average

Farm Class	Single Owner	All Farms	Single Owner %
Class 1	130	220	59%
Class 2	640	850	75%
Class 3	790	1,155	68%
Class 4	2,930	4,020	73%
Class 5	1,200	1,490	81%
Class 6	2,230	2,657	84%
Class 7	1,230	1,306	94%
Class 8	410	592	69%
Total	**9,560**	**12,290**	**78%**

Source: B+LNZ Sheep and Beef Farm Survey

Similar information is not available for the deer industry. However, a study on high country deer farms identified that “second generation members of deer farming pioneers” tended to farm more extensively and for their “affinity” to deer. Farmers who had diversified into deer or were managers of corporate farms that tended to be managed more intensively and view deer as “just like other stock” (Peoples & Asher, 2012). Different management perspectives were described as being either that “farms need to adapt to deer, or deer need to adapt to farms”.

Farming to Natural Capital vs. External Inputs

One factor shaping decision-making for drystock farmers is the limited extent of infrastructure development or use of external inputs. Beyond the development of systems for self-feeding of silage/baleage/conserved feed, and fertilising naturally productive paddocks to maximise pasture/crop production, drystock farms are generally low input systems that adapt to, and rely heavily on, the environment to produce meat, velvet or wool. In this case, there is an environmental limit for pasture/feed production that dictates the number of stock that can be farmed, and the rate at which the stock can grow to produce the desired production target (e.g. a carcass weight of 60 kg for the chilled venison market). For example, high country tussock land produces less feed than lowland areas so its carrying capacity is lower. Additional fertiliser or introduction of more productive pasture species would not be commercially beneficial if there was insufficient natural rainfall or mean annual temperature was too low to stimulate potential growth.

Image C1: Sheep farm near Drummond
Source: Emma Moran

Many drystock farmers manage to carry the stock through for the whole year within these constraints. It may require additional feed for periods of the year, (particularly in winter/spring) – either from surplus on-farm production or brought in from outside of the farm. However, it is not a dominant component compared with the on-farm, in-paddock feed supply (of pasture or fodder crops). There is, therefore, a tacit understanding that drystock farming is a low input production system and that considerable external inputs and capital development would be required to boost production above the level attainable from the "natural capital" or capability of the land. The costs of such development (e.g. installing irrigation, wintering barns, external feed supplements and feeding out facilities) may then dictate that an alternative range of products (with a higher unit price) would be needed to cover the cost of development.

3. Dairy

Summary Points

41 case study dairy farms were used to estimate the impacts of reducing nitrogen and phosphorus losses. These farms were spread across Southland and were diverse in farm system and management. They do not represent an average farm but were selected to test a range of mitigations on different dairy farm types.

There was a wide range in nutrient losses between farms due to differences in soil drainage, rainfall, farm systems and management. Each farm is unique and what may be effective and viable for one farm may not be for another. There were no significant differences in nutrient losses between the FMUs.

The mean nitrogen loss for the 41 farms was 38 kg N/ha/year with 55% of farms leaching between 25 and 45 kg N/ha/year.

The mean phosphorous loss for the 41 farms was 0.9 kg P/ha/year with 58% between 0.5 and 1.1 kg P/ha/year.

In the absence of any specific policy, an output approach was adopted where a 10%, 20%, 30% and 40% reduction in both nitrogen and phosphorous losses were targeted for each farm separately.

Not all farms were able to achieve the targeted nutrient loss reduction before significant farm system, infrastructure or land use changes. Approximately 80% of farms could not achieve a 20% reduction in phosphorous loss before having to retire land.

In general, the higher the reduction in nitrogen and phosphorous loss the larger the impact on operating profit.

Authors: Matthew Newman (Senior Economist), Carla Muller (Agricultural Economist), **DairyNZ.**

This section covers the process used in selecting case study dairy farms and creating nitrogen and phosphorus mitigation curves for these farms. It also presents the results and discusses the assumptions and limitations of the modelling.

3.1. Case Study Farm Selection

The key components influencing nutrient losses on dairy farms are soil drainage, rainfall and the intensity of the farm system. These elements were considered to ensure a range of farms were selected for each FMU. Given the size and diversity of dairy farming in Southland it was determined that approximately 40 farms should be selected as case study farms.

The final sample was 41 farms, 40 case study dairy farms were supplemented with a composite farm (based on real farm data) in an area where there was not a lot of farms, so confidentiality of individual farms could be protected. In total approximately 4% (9,586 effective milking platform hectares across the 41 farms) of the dairy land in Southland was analysed for this project (Table C18)

A case study approach ensures relevant empirical data is used to describe the 41 farms. An issue with this method is that it can be challenging to find farms that are typical due to every farm being a unique combination of environmental and management characteristics. The use of actual farm data collected through DairyBase provides data that is realistic, validated and is treated consistently between farms.

In Southland, there are different water quality issues in each of the receiving waterbodies and it is important to understand how various farm systems could respond to help address specific catchment issues. For example, it is important to understand how different farm systems operate on particular soil types, as opposed to transplanting an average farm onto the range of soil types, particularly when the soil type affects the way a farm is managed. Farms were selected based on their location, environmental characteristics (rainfall and soil drainage) and farm system. The farmer's willingness to be involved and the suitability of the farm in terms of data availability, complexity of farm operation and ownership also contributed to farm selection. There is likely to be some bias in the sample, as those likely to agree and those with reasonably good records will tend to be better than average performers, although this does not necessarily mean they will have higher or lower nutrient losses than other farmers. However, many of the farms selected for this study were considered reasonably typical to specific areas (based on rural professionals' opinions).

The geographical spread of the selected farms was checked to ensure that farms were located across the FMUs and that the number of farms roughly corresponded to the total number of dairy farms and hectares in that FMU. A geographical spread of farms across the four FMUs ensured a mix of rainfall and soil types were covered. In addition, farm systems characteristics such as farm size, intensity of farms, imported supplementary feed, wintering practices (including cropping), irrigation, off pasture structures and profitability were considered in the farm selection process. Table C18 summarises the distribution of case study farms across the FMUs by soil type and rainfall.

Once farms were selected, a data collector visited each farm to fill out a DairyBase questionnaire. In addition, consent was gained for DairyBase to access and analyse the latest farm accounts. The data obtained was used to set up base OVERSEER and FARMAX files for each farm.

An OVERSEER file is set up based on blocks which are areas of a farm with the same characteristics and under the same management. Each block contains a group of paddocks and any mitigation applied to a block pertains to all paddocks in that block. The impact of mitigating nutrients on both the milking platform and support blocks were analysed where the support block was either owned or leased and there was enough information to create OVERSEER and FARMAX files.

Table C18: Dairy effective milking platform hectares by rainfall and soil drainage[11]

Dairy	Waiau	Aparima	Ōreti	Matāura	Total
Predominantly well or moderately well-drained soil & <1,000 mm average annual rainfall	225	0	0	845	1,070
Predominantly poor or imperfectly drained soil & <1,000 mm average annual rainfall	0	403	222	912	1,537
Predominantly well or moderately well-drained soil & >1,000 mm average annual rainfall	291	1,326	423	832	2,872
Predominantly poor or imperfectly drained soil & >1,000 mm average annual rainfall	0	685	1,715	1,707	4,107
Effective milking platform hectares sampled	516	2,414	2,360	4,296	9,586
Total dairy hectares in FMU	11,961	49,052	85,376	70,272	216,661
% of sampled dairy land in each FMU[12]	4.3%	4.9%	2.8%	6.1%	4.4%

3.1.1. Waiau

In the Waiau FMU, three farms were selected; with all farms situated on predominantly well or moderately well-drained soils. Rainfall ranged between 950 and 1,216 mm per year. None of the selected Waiau farms were irrigated or had an off pasture structure such as a stand-off pad. All three farms were medium input systems. The farms ranged in size from 138 to 225 eff. ha (milking platform) and had stocking rates from 2.7 to 3.2 cows per eff. ha (milking platform). On average the farms ran 3.0 cows per eff. ha on 153 eff. ha (milking platform). Their production ranged from 1,129 to 1,330 kg milksolids per eff. ha, with an average of 1,260 kg of milksolids per eff. ha (milking platform).

One of the case study farms in the Waiau was a composite farm, based on the average of four dairy farms located in the Te Anau Basin. This ensured confidentiality for the farmers in this area. S-Map was used to find the predominant soil types and the NIWA Climate Station tool in OVERSEER was used to find the average rainfall for the four farms. This information was then used in the composite farm.

On average the three case study farms had an ineffective area equal to 15% of their effective milking platform and support block land area. This is higher than the other FMUs which had ineffective areas ranging from 7% to 13% of effective land area. Of the three farms modelled in the Waiau FMU, one had a support block which was 41% of the size of the effective milking platform (this support block was included in the modelling).

All of the case study farms grew crops (summer and/or winter), with a range from 3% to 13% of effective land area (milking platform and support block) used for cropping. The effluent application area, as a proportion of the effective milking platform, ranged from 27% to 63%.

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[11] Table C18 builds on an earlier table in "General Approach" section at the start of Part C.

[12] Based on milking platform effective hectares from sample farms divided by estimated milking platform total from Environment Southland.

3.1.2. Aparima

In the Aparima FMU, 11 farms were selected; with six farms situated on predominantly poor or imperfectly drained soils and the remaining five farms on predominantly well or moderately well-drained soils. Rainfall ranged between 906 mm and 1,383 mm per year. One farm was irrigated. All system types were represented with eight medium input farms, two high input farms and one low input farm.

The farms ranged in size from 96 to 365 eff. ha (milking platform) and had stocking rates from 2.6 to 3.2 cows per eff. ha. On average, the farms ran 2.9 cows per eff. ha on 221 eff. ha (milking platform). Their production ranged from 1,023 to 1,687 kg milksolids per eff. ha (milking platform), with an average of 1,349 kg of milksolids per eff. ha (milking platform).

Of the 11 farms seven had support blocks (owned or leased), these were included in the modelling. These ranged in size from 36 eff. ha to 240 eff. ha. On average the case study farms had an ineffective area equal to 13% of their effective milking platform and support block land area.

All of the farms grew crops (summer and/or winter), with a range from 3% to 21% of effective land area (milking platform and support block) used for cropping. The effluent application area, as a proportion of effective milking platform, ranged from 17% to 87%, with an average of 85 hectares, or 39% of the effective milking platform.

3.1.3. Ōreti

In the Ōreti FMU, 13 farms were selected; with ten farms situated on predominantly poor or imperfectly drained soils and three farms on predominantly well or moderately well-drained soils. Rainfall ranged between 922 mm and 1,154 mm per year. All system types were represented with six medium input farms, four high input farms and three low input farms.

The farms ranged in size from 115 to 279 eff. ha and had stocking rates from 2.5 to 3.5 cows per eff. ha. On average the farms ran 2.9 cows per eff. ha on 189 eff. ha. Their production ranged from 1,064 to 1,608 kg milksolids per eff. ha, with an average of 1,283 kg of milksolids per eff. ha.

Of the 13 farms five had support blocks (owned or leased). These ranged in size from 12 eff. ha to 130 eff. ha. On average, the case study farms had an ineffective area equal to 7% of their effective milking platform and support block land area.

Eleven of the farms grew crops (summer and/or winter), with a range from 3% to 14% of effective land area (milking platform and support block) used for cropping. The effluent application area, as a proportion of effective milking platform, ranged from 19% to 85%, with an average of 75 hectares, or 40% of the effective milking platform.

3.1.4. Matāura

In the Matāura FMU, 14 farms were selected; with seven farms situated on predominately poor or imperfectly drained soils and seven farms on predominantly well or moderately well-drained soils. Six farms were classed as Upper Matāura and eight were classed as Lower Matāura[13] . Rainfall ranged from 802 mm per year to 1,378 mm per year. The six farms in Upper Matāura all received under 1,000 mm of rain per year in comparison to the eight farms in Lower Matāura which received over 1,000 mm per year. Two farms were irrigated. All system types were represented with nine medium input farms, three high input farms and two low input farms.

The farms ranged in size from 146 to 717 eff. ha (milking platform) and had stocking rates from 2.1 to 3.2 cows per eff. ha. On average, the farms ran 2.8 cows per eff. ha on 308 eff. ha (milking platform). Their production ranged from 763 to 1,546 kg milksolids per eff. ha (milking platform), with an average of 1,168 kg of milksolids per eff. ha (milking platform).

Of the 14 farms, nine had support blocks (owned or leased); these were included in the modelling. They ranged in size from 32 eff. ha to 558 eff. ha. On average, the case study farms had an ineffective area equal to 10% of their effective milking platform and support block land area.

Thirteen of the farms grew crops (summer and/or winter), with a range from 1% to 16% of effective land area (milking platform and support block) used for cropping. The effluent application area, as a proportion of effective milking platform, ranged from 14% to 100%, with an average of 118 hectares, or 38% of the effective milking platform.

3.1.5. Infrastructure

The infrastructure on the sample farms included off pasture structures on the milking platforms such as feed pads, stand-off pads and housing. There were a total of 18 off pasture structures on 17 of the sample farms with eight structures in Matāura, seven in Ōreti, three in Aparima and none in Waiau. A wintering pad, animal shelter or housing was the most common structure type, stand-off pads and feed pads being the least common, only two farms had wintering barns. Feed for off pasture structures is either purchased or made on farm.

The following Table C19 shows the distribution of off pasture structures by type and FMU. These structures are defined as per OVERSEER. A feed pad is a hard surface area where stock can be held for some time (short periods with no area for all cows to lie down) and provided with supplementary feed. A winter stand-off and loafing pad is a specially built area where stock can be withheld from pasture. In OVERSEER animals cannot be fed on this type of structure. A wintering pad, animal shelter or housing is an area where animals are withheld from pasture for extended periods and supplementary feeds are brought to them. As this structure type can be used for long periods of time the animals require an area to lie down as in stand-off pads, as well as additional space for feeding. This structure type is not further broken down in OVERSEER to identify wintering pads versus barns and therefore, not all 11 farms with structures have a barn.

[13] The split was north or south of Gore.

Table C19: Structures on-farm, by FMU

	Feed pad	Winter stand-off and loafing pad	Wintering pad, animal shelter or housing	Total farms with structures
Matāura	0	1	7	8
Ōreti	2	2	3	7
Aparima	0	2	1	3
Waiau	0	0	0	0
Total	2	5	11	18

3.2. Baseline

The aim of the dairy modelling was to determine the costs of achieving a given level of nutrient loss mitigation for a farm. To do this, mitigation curves were constructed for the 41 dairy farms in Southland.

This modelling work was done prior to Environment Southland releasing the draft Land and Water Regional Plan and makes no attempt to model the draft regulations contained within that document.

OVERSEER (Version 6.2.0) and FARMAX (Version 6.6.5.00) were both used for the modelling to investigate mitigation options. In FARMAX the user can create farm scenarios which can then be checked for feasibility (of feed demand and supply) and the financial impact of mitigation options, while OVERSEER allows the estimation of the impact of mitigation options on nitrogen and phosphorus loss.

An OVERSEER file was created for each farm from data collected for the 2013-14 season. All of the OVERSEER files were created using the OVERSEER Best Practice Data Input Standards and the farm data collected. Some adjustments for irrigation use occurred to ensure that the file represented a reasonably typical season as per the OVERSEER Best Practice Data Input Standards (OVERSEER Ltd., 2015). This was to ensure that the files did not violate one of the underlying assumptions of OVERSEER, which stipulates that a long term steady state is modelled. For example, if irrigation was used longer than normal in a season, adjustments were made to represent a more typical year.

3.2.1. Baseline Results

Nutrient Loss

There was a wide range of base nitrogen and phosphorus losses for the case study farms. Figure C40 and Figure C41 show the distribution for the 41 farms and include the nutrient loss from the total farm modelled (including ineffective area).

The average nitrogen leaching per hectare was 38 kg N/ha/year for the 41 Southland dairy farms with a median of 39 kg N/ha/year. Overall, 59% of farms had nitrogen leaching between 25 and 45 kg N/ha/year and the full range was between 19 and 90 kg N/ha/year. A cluster of farms had nitrogen leaching above 55 kg N/ha/year. Some modelling experts have expressed concerns over how OVERSEER is handling some of these farm types and have suggested there are likely to be overestimations of nitrogen leached per hectare for these farms.

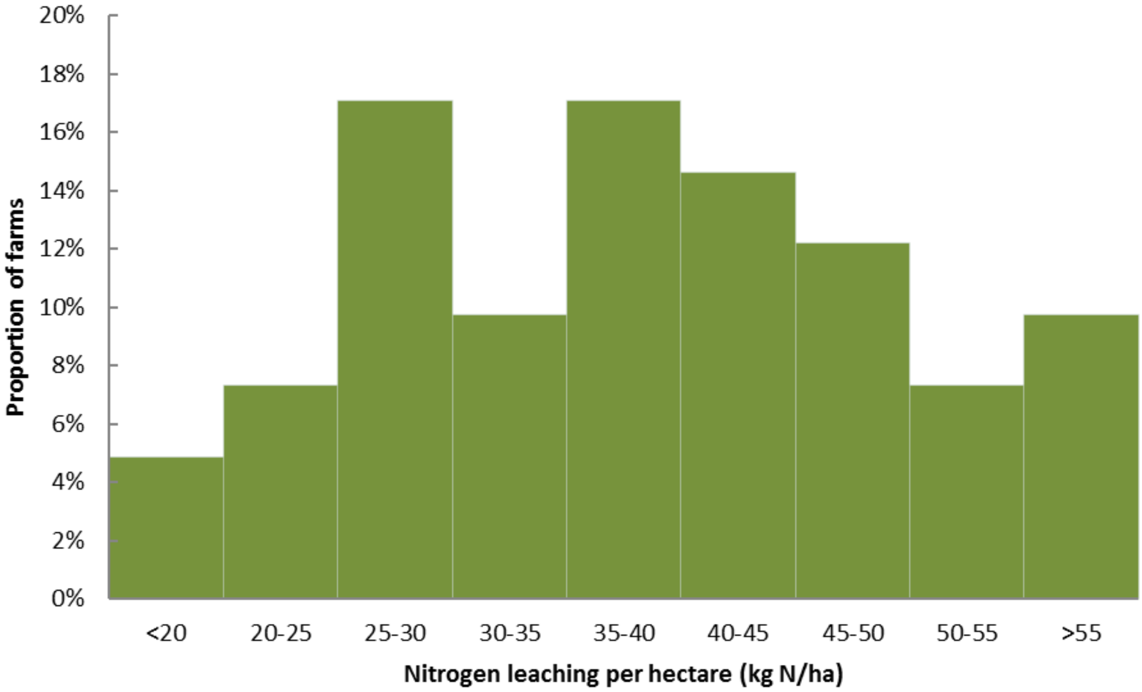

Figure C40: Distribution of nitrogen leaching per hectare (total hectares) for 41 case study dairy farms

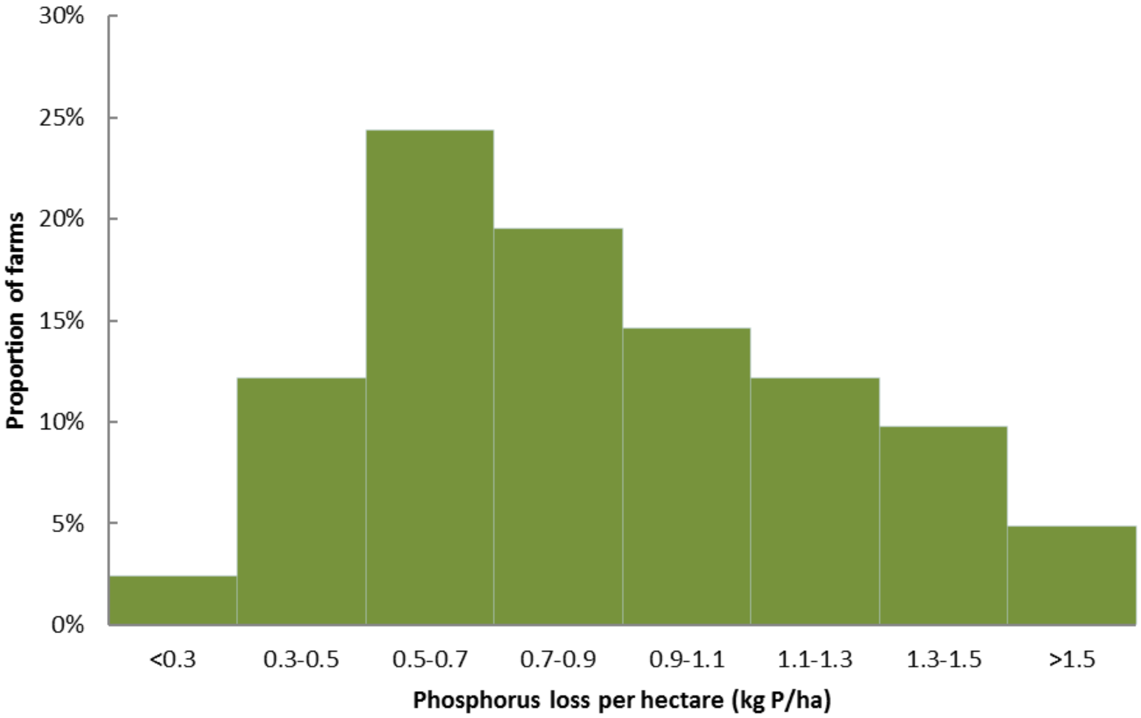

Figure C41: Distribution of phosphorus loss per hectare (total hectares) for 41 case study dairy farms

The average phosphorus loss per hectare was 0.9 kg P/ha/year for the 41 Southland dairy farms with a median of 0.8 kg P/ha/year. Overall, 44% of farms had a phosphorus loss of between 0.5 and 0.9 kg P/ha/year, with 15% below 0.5 kg P/ha/year and 41% over 0.9 kg P/ha/year.

The following tables show the nitrogen and phosphorus losses for groups of farms from this study. The numbers shown are for the 41 case study farms only not all farms in the region. The tables include results for the total area of each case study farm: including effective and ineffective areas, and support blocks where applicable. Table C20 shows the results by FMU, while Table C21 shows environmental and farm system differences.

Table C20: Case study average base nutrient loss results by FMU (total hectares)

Group	**Sample Size**	**Nitrogen leaching (kg N/ha/year)**			**Phosphorus leaching (kg P/ha/year)**		
		Low	Median	High	Low	Median	High
Waiau	3	35	40	55	0.64	0.81	1.01
Aparima	11	25	39	77	0.44	1.38	1.75
Ōreti	13	19	38	58	0.35	1.42	1.75
Matāura	14	19	39	90	0.27	0.64	1.23
Upper Matāura	6	19	42	90	0.27	0.64	1.23
Lower Matāura	8	20	30	49	0.47	0.64	1.23
Waiau (milking platform only)	3	18	40	55	0.64	0.86	1.01
Aparima (milking platform only)	11	25	39	79	0.45	0.98	1.74
Ōreti (milking platform only)	13	19	35	58	0.35	1.11	1.72
Matāura (milking platform only)	14	12	33	86	0.27	0.64	1.30

Table C21: Case study average base nutrient loss results by environmental and farm system groups (total hectares)

Group	Sample size	Nitrogen leaching (kg N/ha/year)			Phosphorus leaching (kg P/ha/year)		
		Low	Median	High	Low	Median	High
Soils							
Poorly and imperfectly drained soils	23	19	30	46	0.48	1.02	1.75
Moderately well and well-drained soils	18	20	46	90	0.27	0.72	4.38
Poorly and imperfectly drained soils (milking platform only)	23	12	30	46	0.52	0.96	1.74
Moderately well and well-drained soils (milking platform only)	18	17	42	86	0.27	0.72	1.65
Climate							
Annual rainfall above 1,000 mm	31	19	39	77	0.35	0.89	1.75
Annual rainfall below 1,000 mm	10	19	36	90	0.27	0.69	1.38
Inputs							
High input farm systems	8	25	44	73	0.48	0.99	1.44
Medium input farm systems	26	19	36	90	0.47	0.82	1.75
Low input farm systems	7	23	39	46	0.27	0.6	0.96
Structures							
Farms with off pasture structures	17	20	39	58	0.35	0.64	1.74
Farms without off pasture structures	24	19	39	90	0.27	0.95	1.75

Comparison of Base Physical Results When Including or Excluding Support Blocks

When the milking platforms were analysed alone and the support blocks were removed from the nutrient loss figures, the model was adjusted by proportioning the 'other' category for nutrient loss in OVERSEER between the milking platform and the support block according to the proportion of effective area for each block of land. The ineffective area was proportioned between milking platform and support blocks according to farmer information.

For some of the farms that had both the support block and milking platform modelled (22 farms) the nutrient loss was higher on the support block and on others it was higher on the milking platform. Some farms had a higher loss of one nutrient from the milking platform and a higher loss of the other nutrient on the support block.

For example, farm A was leaching 28 kg N/ha/year and 0.67 kg P/ha/year for the whole farm (support block and milking platform) area. When just the milking platform was considered this changed to 19 kg N/ha/year and 0.74 kg P/ha/year, the support block on its own lost 60 kg N/ha/year and 0.40 kg P/ha/year.

However, farm B was leaching 20 kg N/ha/year and 1.23 kg P/ha/year for the whole farm (support block and milking platform). The milking platform was leaching 28 kg N/ha/year and 1.30 kg

P/ha/year, the support block on its own lost 10 kg N/ha/year and 1.14 kg P/ha/year. Figure C42 shows a comparison of these two example farms for nitrogen.

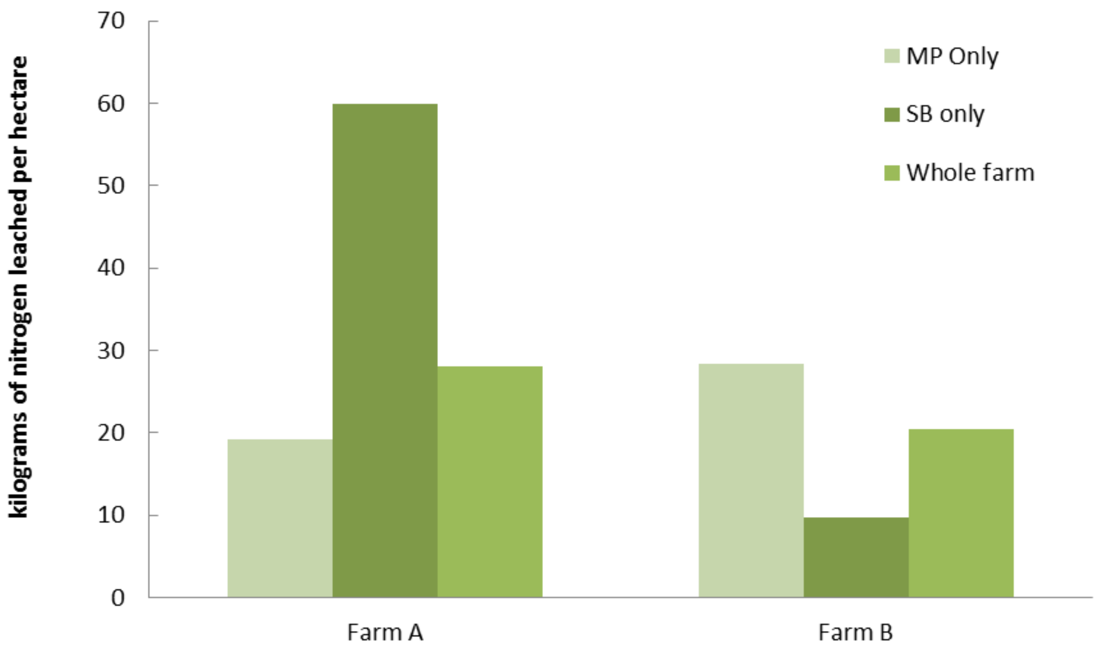

Figure C42: Comparison of nitrogen leaching for two farms when including or excluding the support blocks (total hectares)

There appeared to be a link between the size and use of the support block and how it influenced the nitrogen loss when combined with the milking platform. This is shown in Figure C43. Farms with large pasture dominated support blocks tended to experience a lower nitrogen loss when the support blocks were included and smaller crop dominated support blocks tended to experience a higher nitrogen loss when the support block was included. However, this link did depend on how the milking platform itself was used, particularly the cropping practices, as well as soil and rainfall on the milking platforms and support blocks, so care should be taken in the interpretation of these results.

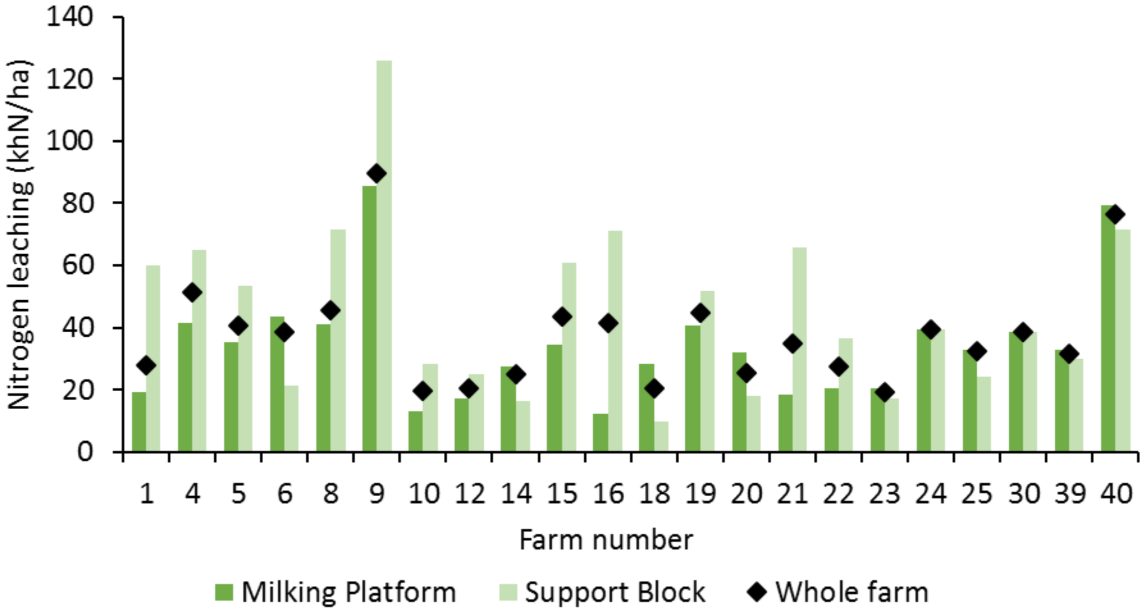

Figure C43: Comparison of nitrogen leaching for farms with support blocks

The differences in phosphorus loss between support blocks and milking platforms on a per hectare basis were much less than those for nitrogen. This is shown in Figure C44.

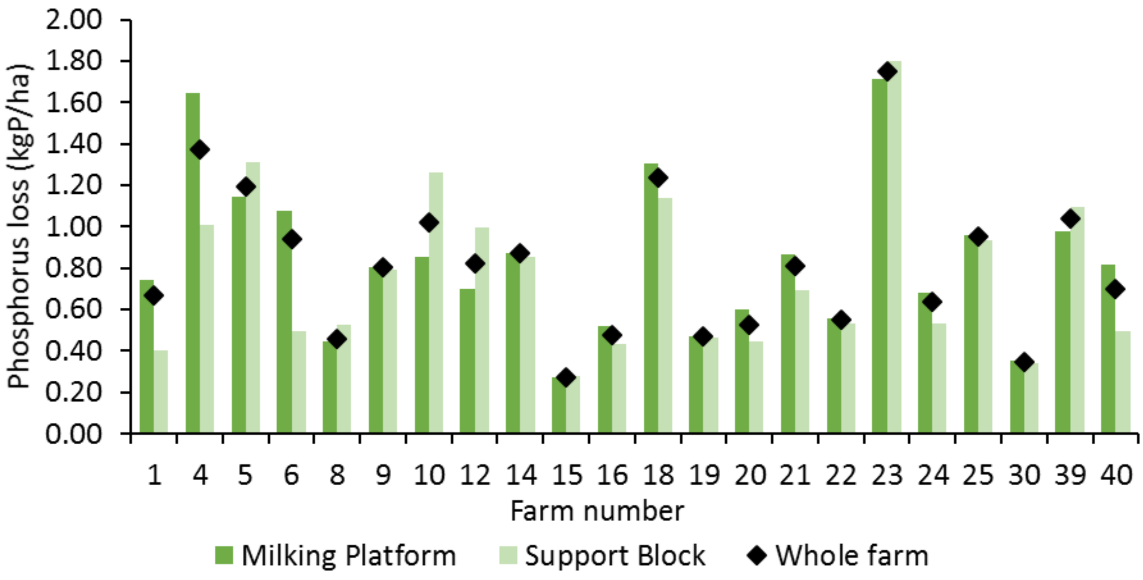

Figure C44: Comparison of phosphorus losses for farms with support blocks

Base Financial Results

Figure C45 shows the distribution of operating profit (on a per effective milking platform hectare basis) for the 41 case study farms at their base position standardised to a $6.50 per kilogram milksolids price. The average operating profit per hectare was $2,850, with a median of $2,830. This operating profit needs to cover interest, rent, tax and debt repayments. A sensitivity analysis of the study results to milk price is discussed at the end of this dairy section.

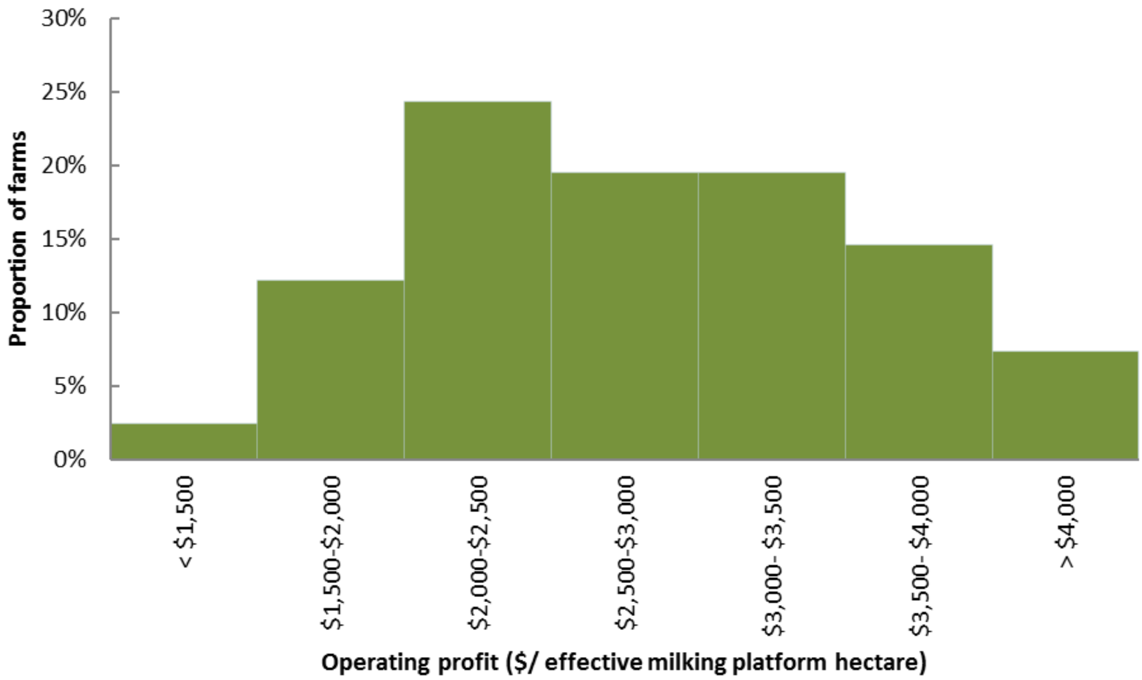

Figure C45: Distribution of operating profit per effective (milking platform) hectare for 41 sample Southland farms

Table C22 shows the average financial position of the case study farms for each FMU. Given the data the industry currently collects there is no way of knowing if this is representative of the wider FMU or of the Southland region. However, the results show a wide range of profitability performance across the 41 sample farms (Figure C45).

Total farm revenue for the sample farms ranged from $5,318 to $11,303 per effective (milking platform) hectare. On average, the farms in Waiau had the lowest revenue, $7,840 per hectare, while the farms in Aparima had the highest average revenue, $9,143 per hectare. Average operating expenses per kilogram milksolids were similar across all FMUs, ranging between $4.16 and $4.65. However, operating expenses for the individual sample farms ranged from $3,681 to $8,165 per hectare. Operating profit (farm revenue less operating expenses) per effective (milking platform) hectare ranged from $1,472 to $4,913 per hectare for the sample farms. It was on average highest for the case study farms in Aparima, $3,128 per hectare, and lowest for those case study farms in Matāura, $2,630 per hectare.

The three largest expense categories are labour, grazing (including support block leases) and supplementary feed (made and purchased). The average labour expense per effective milking platform hectare was $958, which equates to 17% of operating expenses. It ranged from $510 to $1,482 per hectare for the sample farms. On average, grazing expenditure per hectare was $902 per effective milking platform hectare, with a median of $886, and was 16% of total operating expenses. All farms had some grazing costs, however this could include young stock grazing, winter grazing and/or support block leases for grazing or cropping. Supplementary feed was on average $890 per effective milking platform hectare, with a median of $782. This was, on average, 16% of operating expenditure for the 41 case study farms. Interest expenses ranged from $164 per hectare to $2,678 per hectare for the sample farms although this is excluded from operating profit.

There was no relationship between operating profit and nitrogen or phosphorus loss per hectare.

Table C22: Case study farms average base financial position by FMU

	Waiau	Aparima	Ōreti	Matāura
Stocking rate (cows/ha)	3.01	2.95	2.92	2.80
Milksolids (to factory) (kg/ha)	1,260	1,349	1,283	1,168
Revenue ($/ha)	7,840	9,143	8,771	8,049
Operating expenses ($/ha)	5,189	6,015	5,882	5,419
Operating profit ($/ha)	2,650	3,128	2,890	2,630
Revenue ($/kg MS)	6.26	6.78	6.85	6.83
Operating expenses ($/kg MS)	4.16	4.50	4.58	4.65
Operating profit ($/kg MS)	2.10	2.28	2.27	2.25
Labour expenses ($/ha)	874	930	1,005	955
Interest expenses ($/ha)	1,759	1,643	1,463	1,707
Labour expenses ($/kg MS)	0.69	1.28	1.16	1.50
Interest expenses ($/kg MS)	1.41	0.71	0.79	0.81

Note: all values in this table per hectare are per effective hectare for the milking platform only.

3.3. Mitigation Modelling

A mitigation strategy was developed and documented (detailed further in Section 3.2.1) so that all farms followed the same overall process. However, there were some differences in the mitigations applied between farms due to their individual characteristics. The modelling had two main phases. First, nitrogen was mitigated, from the base position (2013-14 season) for each farm, and a 10%, 20%, 30% and 40% reduction in nitrogen leaching was targeted. Then phosphorus was mitigated, again from the base scenario, with a 10%, 20%, 30% and 40% reduction targeted. These mitigations are cumulative (e.g. a 20% reduction builds on the 10% reduction scenario). At each mitigation point, e.g. a 10% reduction in nitrogen leaching, a set of interdependent mitigations are presented and results recorded. This is because the mitigations have to represent a viable farm system and energy supply and demand need to balance, e.g. a reduction in fertiliser cannot be measured in isolation as this will reduce the feed supply and the feed demand must also be reduced.

This method focuses on output based regulations as it allows farmers to develop their own preferred mitigations. Percentage reductions were targeted in the absence of policy but once policy is developed separate modelling could be undertaken to test the specific targets.

One of the assumptions when conducting this modelling was that a mitigation strategy targeting nitrogen could not significantly increase phosphorus losses and vice versa. This is because it is not yet known what the catchment limits will be and if a particular case study farm will be allowed to increase nutrient losses of one nutrient to reduce the other.

The impact of mitigating nutrients on both the milking platform and support blocks were analysed where the support block was either owned or leased and there was enough information to create OVERSEER and FARMAX files. This is due to: the importance of wintering dairy cows in Southland, the high risk potential for nutrient losses from winter cropping, and the lack of certainty about how nutrient loss limits will be set by policy for milking platforms and support blocks. Modelling both the milking platforms and support blocks together means that mitigation strategies can be applied that target wintering practices, which are an important factor in Southland dairying, such as reducing the winter crop area. Results are presented as an amalgamation of milking platform and support block (where one was modelled) unless otherwise stated. However, base nutrient loss results can be separated by milking platform and support block. There will not be separate mitigation curves for the milking platform and support block where a farm has had both modelled due to the difficulty in splitting the financials by milking platform and support block, e.g. labour.

If a farm does not have a support block and cows are off the milking platform for winter at a third party grazier, then the base nutrient loss number will not capture the losses associated with those cows in winter and removes the option of altering wintering practices as mitigations.

Currently, Southland dairy farms are required to apply effluent at a rate below 150 kg nitrogen from effluent per hectare per year. Dairy farms are required under the Sustainable Dairying Water Accord to exclude stock from waterways and most milk companies now require dairy farms to provide information on nutrient use on farm. Industry good management practices for the dairy industry are still being developed. This mitigation modelling does not attempt to predict what is in the Matrix of Good Management but assumes all dairy farms have excluded stock from waterways.

3.3.1. Mitigation Strategies

While the broad mitigation process was similar, there were differences in the mitigations modelled between farms due to their individual characteristics. The mitigation strategies were developed based on experience and farm systems knowledge within the modelling team at DairyNZ. Similar mitigation strategies have been applied and peer reviewed over time in other projects, particularly for nitrogen mitigation[14]; phosphorus mitigation modelling is less understood and has been developed during The Southland Economic Project.

The mitigation strategies applied in this modelling are the most cost effective method of reducing nutrient loss in OVERSEER given the assumptions used and current available technologies. They are not the only possible way to reduce nutrient losses but the least-cost option given the modelling constraints (for example, the constraints of using OVERSEER where certain factors cannot be modelled). If a farm had a particular nutrient loss limit to meet they may choose to undertake a different selection of mitigation options. For example, a farm reducing nitrogen leaching by 10% may choose a different strategy to one that is required to reduce nitrogen leaching by 30%. This research did not attempt to capture every possible mitigation option: it attempted to meet incremental reductions in nutrient loss. In reality, the nutrient loss regulation that a farm faces will likely influence their chosen mitigation strategy.

This work sets two caveats on the mitigation:

1. The farmer is operating a particular system for a reason and will not want to, or may not have the skills to, significantly change this farm system; and
2. Mitigations will stop if the land is no longer required, e.g. feed supply exceeds feed demand in perpetuity, or the land use changes from dairy.

Mitigation strategies can be broadly categorised as management changes within the current farm system (stage one mitigation strategies), and then mitigations which will change the wider farm system (stage two mitigation strategies). This study focused primarily on stage one mitigations although at higher mitigation levels e.g. 40%, there could be significant changes to a farm system through fewer inputs e.g. supplementary feed.

Stage 1 = within system changes: a process in which reductions in farm inputs are sequentially applied on the base farm. These changes are applied to the existing farm system.

Stage 2 = system changes: significant changes to the farm system or significant capital investment. It includes (but not limited to) barns, wetland construction, changes in wintering practices and significant changes in effluent storage and disposal.

The specific mitigation measures applied to each farm differed. No two farms had identical strategies applied due to the unique nature of each farm system, but for confidentiality reasons the details are not included in this report.

The results from these mitigation options were then analysed, particularly the impact on profit (measured by operating profit per effective milking platform hectare), production and nutrient loss. These points were then used to create mitigation curves which show the relationship between estimated nutrient lost per hectare and farm operating profit per hectare (EBIT) at each target point from the original base for each farm. Separate curves were created for nitrogen and phosphorus mitigations.

[14] This includes mitigation modelling by DairyNZ in the Lower North Island, Waikato, Canterbury and some areas in Bay of Plenty.

The methodology, key assumptions and early results were discussed with a small group of Southland farmers. Some of the recommendations from this group were applied to the modelling.

Nitrogen

The nitrogen mitigation strategies are broadly illustrated in Figure C46. This diagram shows the overall process that this study followed when applying stage one mitigation strategies to each case study farm.

Stage one followed a standardised sequence. These can be broadly described by the following:

- If the farm has an existing feed pad, stand-off pad or cow housing facility then the use of this is optimised.
- Autumn nitrogen fertiliser applications are reduced and then removed.
- Spring nitrogen fertiliser applications are reduced and then removed.
- Imported supplements are reduced (up to a 20% reduction from the base).
- The stocking rate is reduced (up to 20% reduction of cow numbers from the base) and the feed supply and demand balanced.

It is important to remember that these steps were not applied in isolation. Each point on a mitigation curve is the result of implementing a set of mitigation options which reduce nitrogen leaching while still balancing feed supply and demand. There were also some farms that were suitable for other mitigation options including changes in cropping practices and the effluent disposal area.

The first option considered in the stage one mitigations was the duration of controlled grazing if a farm had an existing off pasture structure. If the farm had an existing off pasture structure, its usage time was increased (if possible) to reduce the amount of time cows are grazing pasture. The extent that this mitigation option could be used depended on the characteristics of the existing facilities and took into account factors such as animal welfare. This mitigation strategy was limited by the amount of time OVERSEER would allow the usage of a stand-off pad to be increased. At the time of modelling there was a bug in OVERSEER that meant in some cases increased use of the stand-off pad was not a valid scenario and therefore the use of this mitigation option was constrained. This is likely to be addressed in subsequent versions of OVERSEER.

If there was a high risk of nitrogen leaching from effluent disposal, this was addressed. In stage one mitigations the effluent area was allowed to increase by up to 10 hectares (if the effluent area was a high risk area for nitrogen leaching on the case study farm). This mitigation strategy was constrained by the availability of suitable paddocks for effluent disposal. If the effluent block had a different fertiliser programme than the non-effluent block this was also adjusted to reflect the increased effluent area. Any predicted change in pasture production was captured and associated feed demand was adjusted if necessary. Imported feed types were analysed to see if high nitrogen content feeds could be replaced by low nitrogen content alternatives, while maintaining the amount of imported feed used as a proportion of the total dry matter intake. This was considered in relation to the feed types that are currently used in Southland.

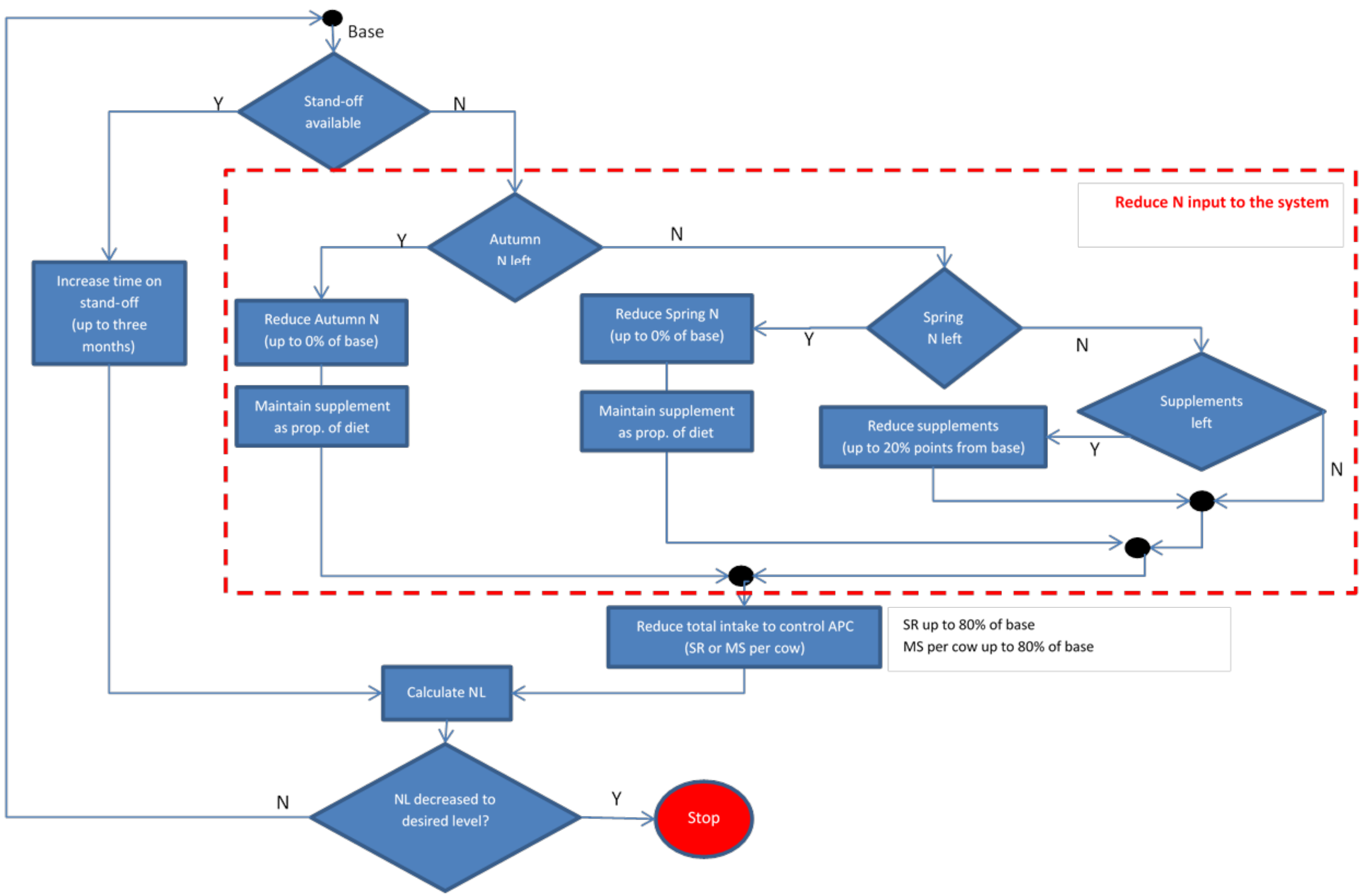

Figure C46: Flow diagram of stage one nitrogen mitigation options

Note: Legend = Au N: autumn applications of nitrogen fertiliser, Sp N: spring applications of nitrogen fertiliser, SO: stand-off pad, NL: nitrogen leaching, SR: stocking rate, MS: milksolids, APC: average pasture cover

The next option considered during stage one mitigation modelling was the application rates and timing of nitrogen fertiliser application. Once the risk of nitrogen leaching from these factors was minimised, the total amount of nitrogen fertiliser used was reduced. Autumn applications were targeted first, followed by spring fertiliser applications (Romera, Levy, Beukes, Clark, & Glassey, 2012); this was done incrementally. At every stage feed supply and demand were balanced in FARMAX. Farmer skill levels were assumed to be constant and therefore production per cow was held constant and feed demand and supply were balanced by reducing cow numbers or increasing the amount of energy provided through imported feed.

If a farm used a crop area during a proportion of the winter period, crops with a lower nitrogen leaching risk factor (as per OVERSEER) were considered as a mitigation option if the alternative crop fitted into the farming system. When considering this option the growing conditions and the suitability of alternative crop types were taken into account. The cropping area could also be reduced, starting with the crops with the highest risk factor for nitrogen leaching. To balance this, the feed demand was reduced, normally through a reduction in stocking rate.

Following these mitigation options, the proportion of purchased feed in the diet was reduced by up to 20% relative to the original scenario. Once again the reduction in feed supply needed to be balanced by an equivalent reduction in feed demand.

Each of these steps reduced the feed supply, this was offset by reducing the feed demand to achieve appropriate pasture covers and avoid feed gaps throughout the year in FARMAX. This was done either by reducing the stocking rate or the amount of feed eaten per cow, according to the judgment of the modeller. Regardless of the policy selected, the milk production per hectare declined because this modelling uses the assumption of constant milksolids production per cow (as a proxy for farmer skill). Reducing production per hectare may not impact significantly on the farm profit but may have implications for milk processing.

The mitigation process was continued until all the bounds (Figure C46) were reached. These bounds are constraints on how far certain factors i.e. the amount of supplement fed (as a proportion of total feed offered per cow), per cow production, and stocking rate; can be altered from the base farm system. This is because drastic changes in any of these variables are likely to disrupt farm management considerably, and it would be difficult to predict how farmers would adjust. However, there are likely to be some farmers who dramatically change farm systems over time due to nutrient management and reduction requirements. Given these bounds it is also possible that land use changes will occur but analysing these is beyond the scope of this study. In this study stage two mitigation modelling included selecting farms that had suitable characteristics and applying capital intensive mitigation options. These are described in Section 3.3.1 Stage two mitigations.

Phosphorus

Phosphorus mitigation employs the same two stage process as nitrogen mitigation, with de-intensification followed by system changes. Figure C47 shows the overall process that this study followed when applying stage one phosphorus mitigation strategies to each case study farm.

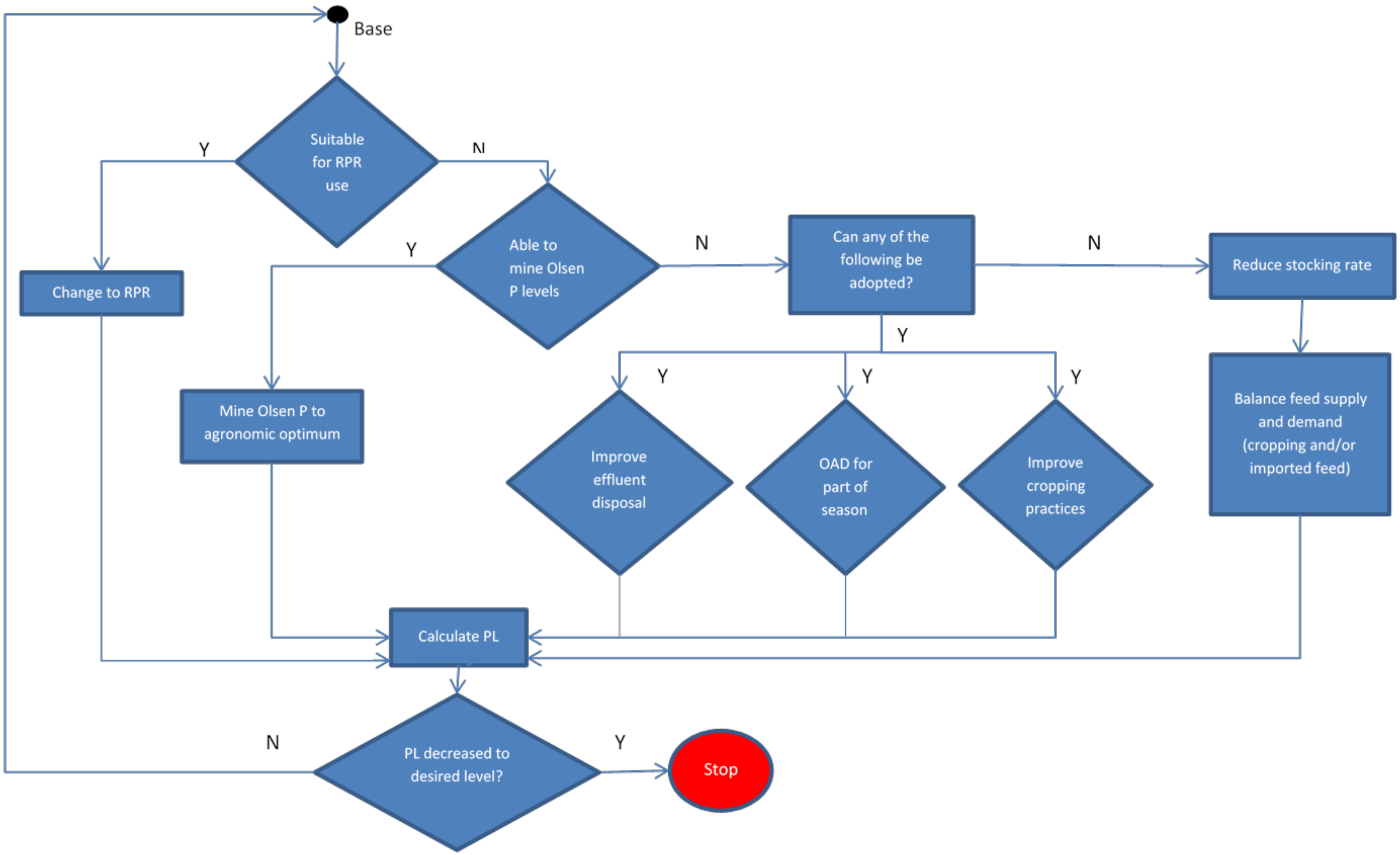

Figure C47: Flow diagram of phosphorus mitigation options

Note: Legend = RPR: Reactive Phosphate Rock fertiliser, PL: phosphorus loss, OAD: once a day

Phosphorus mitigation in stage one follows a standardised sequence. These can be broadly described as:

- If the farm is suitable for the use of RPR any phosphate fertilisers are swapped to this.
- If the farm has Olsen P levels above the agronomic optimum (Olsen P 30) then these are reduced to the agronomic optimum.
- The key areas of risk that are unlikely to impact significantly on production are identified, and addressed where appropriate, this includes effluent and cropping practices.
- The key areas of risk that may impact on production are identified and addressed where appropriate, this includes the use of once a day milking (OAD) for part of the season and decreasing cropping areas.
- The stocking rate is reduced (up to 20% reduction of cow numbers from the base) and the feed supply and demand balanced.

The first phosphorus mitigation strategy considered was the use of RPR instead of superphosphate fertilisers. However, RPR is not a suitable alternative to other phosphate fertilisers for every farm. To determine which farms in this study were suitable for RPR, selection criteria were developed based on Sinclair, Dyson and Shannon (1990). RPR can be used when the annual rainfall is above 800 mm, soil pH is less than 6, and phosphate retention is lower than 95%. Plant available phosphorus is released at a slower rate from RPR than superphosphate (Sale, et al., 1997); in order for it to be used with no negative impact on pasture production it should be used in areas where Olsen P levels are above the agronomic optimum.

There are also other factors to consider when using RPR, in particular the impact on soil sulphur and acidity levels. Sulphur deficiency is prevalent in many New Zealand soils and adequate sulphur is essential for pasture production. Superphosphate contains sulphur while RPR does not, therefore sulphur may need to be applied as well when changing from superphosphate to RPR. For this reason RPR Sulphur Super (RPR 15 S) was used on some case study farms in order to maintain the same additions of phosphorus and sulphur. It is also important to consider the effect of soil pH levels; the optimal pH for the dominant dairy farming ryegrass and clover based system is 5.8-6.0. Altering this may affect pasture production and factors such as trace element availability, which could have flow-on effects to animal health. The timing of fertiliser applications will have an impact on the phosphorus losses. If fertiliser is applied when runoff is unlikely then the runoff from a high water-soluble phosphate fertiliser (e.g. superphosphate) can be similar to that from low water-soluble phosphate fertilisers (e.g. RPR)[15].

The next mitigation strategy that was applied as part of the stage one mitigations was mining Olsen P levels when these were above the agronomic optimum. Soils with high Olsen P values are at greater risk of phosphorus loss, therefore reducing Olsen P levels will reduce the phosphorus losses from a farming system (McDowell & Catto, 2005). Olsen P levels below the agronomic optimum will reduce pasture production. If Olsen P levels are above the agronomic optimum and are reduced to this level there will be a minimal negative impact on pasture production (Roberts & Morton, 1999) as Olsen P levels above the agronomic optimum do not significantly increase pasture production. For sedimentary soils the target Olsen P to achieve near maximum pasture production is 20-30 and 35-45 for peat soils, for this study the optimum Olsen P level was defined as 30.

In the base files developed in this study, the Olsen P values provided by farmers were used, if a farmer had not provided these the default value from OVERSEER was used (Olsen P of 30). Farms that had Olsen P levels below 30 were maintained at that level. However, this situation is likely to be limiting their potential pasture production and these farms may look to increase their Olsen P levels. This should not increase phosphorus losses as the plants will be able to utilise the plant available phosphorus up to the agronomic optimum above which the risk of increased phosphorus losses will increase.

Farms that provided Olsen P values that were above the agronomic optimum were decreased to 30. On farm Olsen P levels can be reduced over time by reducing phosphate fertiliser applications. This needs to be monitored through soil testing to ensure the desired level is reached and Olsen P levels do not drop below optimum. As a result, OVERSEER provides a steady state for a year it does not capture the time taken to reduce Olsen P levels, which can take years (Monaghan, Hedley, Di, McDowell, Cameron, & Ledgard, 2007), this time lag is not taken into account in the models. For the farms that were able to provide Olsen P values it was assumed that they were undertaking soil tests and therefore there was no additional cost of reducing Olsen P levels. While Olsen P levels were entered at a block level (the average Olsen P from the paddocks in that block), there may be variations in Olsen P levels between paddocks, or even within a paddock, which will need to be considered when applying this mitigation on farm.

Next, further stage one phosphorus mitigation strategies were considered. On some case study farms phosphate fertiliser application practices were improved. This included changing applications to months when the risk of runoff was lower and splitting large applications into multiple smaller ones, this incurred additional spreading costs.

Following this, effluent disposal was considered. If effluent disposal was a high risk for a farm then this was targeted. This included an increase in the disposal area by up to 10 hectares. Where effluent discharge was a high risk activity for phosphorus loss, application rates were also considered and where applicable these were reduced. Whether this policy could be implemented depended on the effluent disposal method and if it was able to be upgraded without significant capital investment. Some farms had new travelling irrigators installed; the depreciation costs for this were included in the mitigation curves but the capital cost and interest costs were added to the balance sheets provided for **The Southland Economic Model for Fresh Water**.

Phosphorus loss was quite challenging to mitigate on many of the case study farms. One mitigation that reduces phosphorus loss in OVERSEER and does not require capital investment is switching from twice a day milking (usual practice on dairy farms) to once a day milking. However, this mitigation strategy does negatively impact on production. The magnitude of impact will be influenced by the length of time this strategy is used. This mitigation strategy involved changing to once a day milking at the end of the season and in some cases going once a day milking from Christmas time. This mitigation was balanced with reduced production per cow and altered feed (imported supplements and crops).

Cropping was also targeted to mitigate phosphorus loss. Initially cropping practices were improved if applicable, including cultivation methods that disturbed the soil less, reducing the time left fallow (accounting for soil and weather conditions) and crop types. Following this, the cropping area of the highest risk crops (in terms of phosphorus loss) was reduced. This was balanced with the potential pasture production from the land which was no longer growing a crop and reduced cow numbers.

After these mitigations were considered, stocking rates were reduced and balanced with reduced feed supply (imported feed and crops). Stocking rates were not reduced below the point where pasture was surplus to requirements and land would need to be retired.

Stage Two Mitigations

Stage two mitigations for nitrogen and phosphorus were also considered. Some farms were selected for mitigations that have a large impact on farm systems and/or a large capital cost. The stage two mitigations that were considered were: barn construction, wetland creation, gibberellic acid applications, installation of grass filter strips and significant changes in effluent storage and disposal. To be selected a farm had to be suitable for the proposed mitigations. For example, if a farm was flat or had artificial drainage, then it was not able to have grass filter strips applied in OVERSEER.

The capital costs were captured outside of the mitigation curves that were generated from stage one mitigation results as they were beyond operating profit. The capital costs were calculated based on existing literature and studies, including Askin and Askin (2014).

The challenge with investigating stage two mitigations was that there was no way of knowing what type of barn or wetland each farmer would construct, how much it would cost, or the potential benefits from it. These would differ for every farm and therefore this level of mitigation modelling has a high level of uncertainty and the results should only be considered on the case study farm they are applied on and not extrapolated to the region or FMU.

The results of these mitigation scenarios are presented in Section 3.4.2 Stage Two Mitigation Results. However, after analysing each mitigation some were excluded for various reasons; these reasons are also discussed in Section 3.4.2.

3.3.2. Assumptions

Underpinning the modelling are a range of assumptions. While each farm may have individual assumptions, there are some key assumptions built into the modelling that are consistent across all farms. For farms to be comparable, the base FARMAX and OVERSEER files need to be treated in the same way.

A milk price of $6.50 was used to reflect the longer-term average price and long term expectations. It is based on the average price received including dividend payments for owner operators for the five years prior to, and including, the season modelled (2013-14), as well as the forecast milk price for the two seasons after this. This assumption will significantly impact on the ability of farmers to pay for mitigation each season. Due to the sensitivity of this assumption it is explored in a sensitivity analysis section. It will also impact on the decisions made on farm each year, such as culling decisions, which will impact on the nutrient loss from a farm.

Fertiliser and feed prices were standardised across all farms and based on the volume and type each farm used multiplied by a standard price for different inputs from FARMAX. These were based on prices in the 2013-14 season. Standard feed and fertiliser prices are important; as mitigation options change these farm inputs and farm financials are adjusted accordingly. For example, nitrogen fertiliser was priced at $1.63 per kilogram of nitrogen[16].

All farmers will need to understand their nutrient loss to be sure they are operating good management practices. It is likely that some form of nutrient budget and/or a farm environment plan will be required to provide compliance data to Environment Southland. On this basis, all farms had an annual cost of $5,000 added to their farm working expenses from the first mitigation for a consultant to provide a comprehensive nutrient budget and plan. Many farms will already have some form of nutrient budget to help with decision making e.g. fertiliser applications. However, there will be some form of reporting and compliance cost in regards to meeting catchment limits. This estimate is based on the costs encountered by farmers to meet reporting and compliance in areas of the Horizons Region.

Changes in labour requirements for a dairy farm are non-linear. Therefore, labour was treated as a fixed cost unless cow numbers dropped significantly (by more than 150 cows), which resulted in one full time equivalent (FTE) employee being removed from the farm system. This meant that if the number of cows was only reduced by a small amount, the farm would not reduce the number of labour units or labour costs.

Throughout this farm modelling, the assumption was made that milksolids production per cow would be held constant. The mitigation strategies employed in this modelling to reduce nutrient loss targeted nutrient inputs. Inputs (fertiliser and supplements) were reduced in successive steps. This created a feed gap, which was addressed by reducing the stocking rate to maintain the same comparative stocking rate. Milksolids production per cow cannot be increased when a feed gap is present on farm. If the modelling reduced the stocking rate and maintained inputs there would be an increase in production per cow because there is more feed for each cow (Romera & Doole, 2014). These assumptions depend on the level of farmer skill being maintained. While farmers can increase their skill level, the time and cost of this would vary for each farmer and this was unable to be captured with any degree of accuracy in this modelling. Therefore milksolids production per cow was held constant as a proxy for farmers maintaining the same skill level. The exception to this was when cows were shifted to a different type of milking interval, for example once a day or three times in 24 hours.

A mitigation curve can be described by a number of parallel curves, with the leftmost curve being an optimum curve representing full management capability, perfect knowledge and full use of optimal resources, including technology (optimised curve in Figure C48). The current farm situation (Point A in Figure C48) is a result of farmer experience, skill and resources. The gap between this optimised

[16] Not all costs are included here as they varied depending on each farms inputs (e.g. type of feed used and what crops were grown) and some of these costs are subject to confidentiality agreements between subscribers and FARMAX and cannot be reproduced without prior approval.

curve and the current curve below it is a management gap as the curve below represents a different level of management capability (Figure C48). If the farmer currently had the skill to create a more efficient farm business (e.g. increase milksolids production per cow for the same set of inputs) than they are currently running, they would already be on the optimised curve. This management gap is shown as between point A and point B on Figure C48, but equally this could be moving from point A to anywhere between point B and C on the optimised curve depending on what is being optimised. For example, point B represented more profit for the same nutrient loss, while point C represents less nutrient loss for the same profit; both points are optimised relative to point A and would require a higher level of management capability.

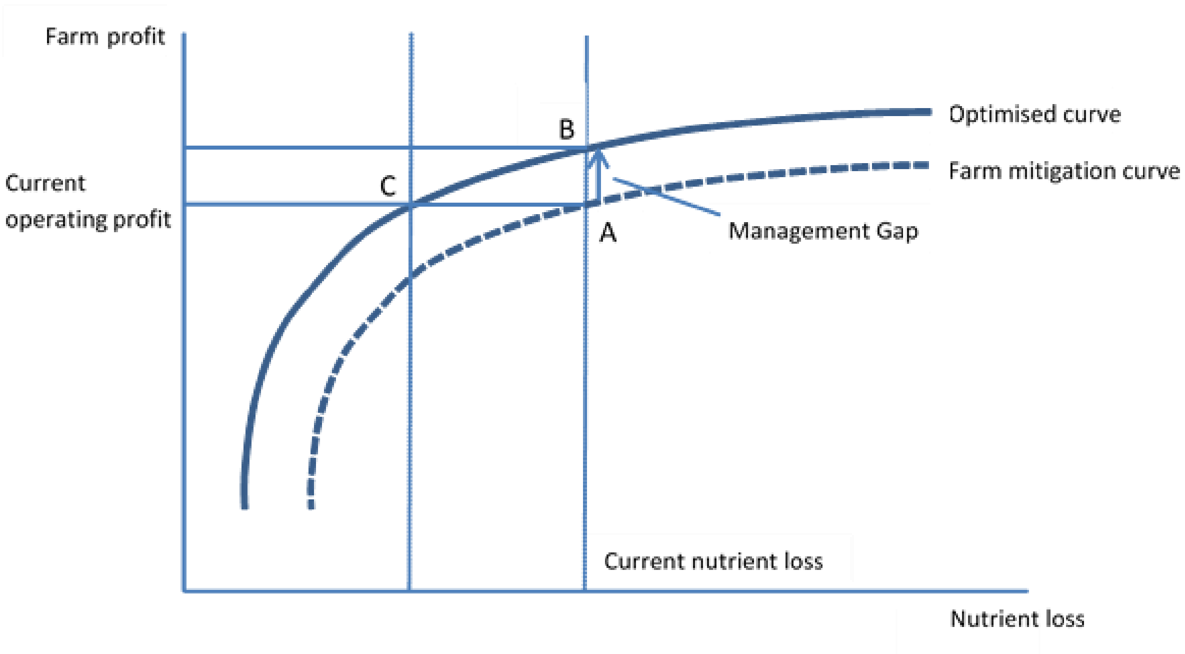

Figure C48: Example mitigation curves showing management gap

During this work it was assumed that mitigation would stop if a dairy farm reached the point where either phosphorus or nitrogen mitigation would cause land to be retired. Retiring land was defined as growing pasture that was unable to be used within the system after meeting the required reduction in nutrient loss. This point is reached when post mitigations pasture is grown that is not required to feed cows on the milking platform in that dairy season, meaning there is a pasture surplus that is either sold or stored indefinitely (i.e. accumulates each year and is not required as feed). The modelling stopped at this point because this land is essentially not being used as part of the dairy farming operation and is retired from production. While pasture could be harvested and sold, the economic return of this is likely to be lower than an alternative land use. Land use changes could be considered at the catchment level but this was not within the scope of the on-farm modelling.

As discussed earlier in Section 3.3.1, using RPR instead of phosphate fertilisers and decreasing Olsen P levels are not suitable strategies for every farm. RPR was used before reducing the Olsen P where applicable, this ensured that farms which could use RPR as a mitigation strategy had Olsen P levels high enough to prevent reductions in pasture production.

The rules for using RPR on a given block on a case study farm were as follows:

1. Olsen P above 30;
2. Soil pH is below 6.0;
3. Rainfall is above 800 mm per year;
4. P retention is less than 95%; and
5. If phosphorus loss was already low e.g. 0.3 kilograms of phosphorus per hectare then RPR was not used.

Where farms had provided information on owned or leased support land this was included in the modelling. Refer to Section 3.3 Mitigation Modelling.

If a farm grazed some (or all) of their herd off the farm it was assumed that it would maintain the same proportion of the herd that was grazed off after mitigation modelling. The reason for this assumption was that there was no information about how farms would change their wintering off practices if their herd size decreased. For example, if herd size decreased it could mean a higher proportion of cows could be kept at home (same number of cows) with less sent to the grazier, or vice versa, however this information was unknown and so not included.

On some farms, increasing the effluent area (for nitrogen) or decreasing the application depth (for phosphorus) was used as mitigations. Increasing the effluent area was limited to an increase of less than 10 hectares, beyond this additional pumps etc. are likely to be required and there were data gaps on how much of the farm and which blocks would be suitable for extending the effluent area. Extending the effluent area significantly was used as a mitigation option on one farm. Extending the effluent area by 10 hectares was estimated to cost $4,500[17] ($15 per meter for 300 meters of mainline pipe and hydrants, including installation costs). This was included as a component of repairs and maintenance as opposed to a capital investment.

Decreasing the effluent application depth was also a possible mitigation option for some farms. When using a travelling irrigator for effluent, the application depth is assumed to be between 12 and 24 mm (unless the farmer has better information). To achieve a lower application depth a faster travelling irrigator or a K-line system is required. K-line systems are only a feasible option if solids are separated prior to the effluent application. These changes are likely to require a new pump to cope with higher specifications. This option was therefore priced at $17,500 and included a new pump ($12,000, including wiring, switches and installation with a zero salvage value on the old pump) and a new travelling irrigator ($5,500 including installation)[18]. This was included as a capital investment and therefore only the depreciation costs of this were included in operating profit. A depreciation rate of 8.5% was used. The interest costs of this should be included in a feasibility study.

This study assumed that there were no additional compliance costs resulting from either of these options. However, we charged each farm $5,000 to cover the cost of preparing annual nutrient budgets and any consents or other compliance required. We also assumed that labour and electricity

[17] DairyNZ Economics Team and DairyNZ effluent specialists.
[18] DairyNZ Economics Team and DairyNZ effluent specialists.

costs would remain relatively stable. A higher flow rate would increase electricity costs but this would likely be offset by reduced pumping time.

3.3.3. Limitations and Constraints

There are some limitations in this study's design which relate to the modelling of nutrient loss restrictions on dairy farms. These are discussed below.

The approach used case study farms and while this provided real farm data there is some uncertainty about the degree to which the farms were representative. This is particularly the case given the wide range in systems, the management ability of farmers and the performance of dairy farms in Southland. However, care has been taken to ensure the major factors affecting nutrient loss in the region were represented including: soil type, rainfall and farm system types.

OVERSEER was used to assess the level of nutrient loss on the farms. OVERSEER undergoes constant revision and adjustment with the version available at the time of this study (6.2.0) generating different outcomes to earlier versions. Based on this, one could assume that there will be different impacts and responses in the next version and that care needs to be taken to ensure this is understood when utilising the results presented here for long term planning or extrapolation. There were also issues (bugs) discovered in each version of OVERSEER that could result in illogical results. These meant some mitigation strategies could not be considered in some cases, for example increasing the proportion of the herd using the stand-off pad in May on one case study farm.

The relatively large amount of phosphorus which is lost in storm events that cause washouts and sediment loss cannot be captured in OVERSEER. This means that modelled phosphorus losses may be underestimated on farms where there is a higher occurrence of storms.

It has also been noted that typically 80% of phosphorus losses from catchments originate from 20% of the land area (McDowell, Assessment of Altered Steel Melter Slag and P-Socks to Remove Phosphorus from Streamflow and Runoff from Lanes - Report Prepared for Environment B.O.P., 2007). These areas are termed critical source areas and are created by the interaction of environmental factors, hydrological conditions and management factors. These critical source areas on farms include laneways, races, troughs, gateways and stock camps. Therefore, targeting these critical source areas with mitigation strategies, for example, grazing management strategies which avoid critical source areas at high risk times is a potentially efficient and cost effective method for reducing phosphorus loss (McDowell, Biggs, Sharpley, & Nguyen, 2004). This may be cost effective at a catchment level, but may not be practical within a specific farm system. Many critical source areas on farms cannot currently be modelled within OVERSEER, which assumes best practice is followed. Therefore, it is likely not all phosphorus losses were captured in this modelling and some options that could mitigate losses from critical source areas were not investigated.

There are many factors which influence environmental and financial performance on individual farms. Examples of such factors include: the skills of farm management and labour; the quality of the resources, for example, soils; and the level of debt or the life cycle stage of the farmer who is making the decisions. It was not possible to model the impact of all of these factors. That is not to say they are not important, but rather, the complexity of the real world was beyond the scope of this study. These individual farmer factors will impact on the mitigation options individual farmers chose to use. Without knowing this information this study has attempted to model the lowest cost option of achieving a 10, 20, 30 and 40% reduction in nitrogen and phosphorus (separately) while not increasing the other.

This study was done prior to the setting of water quality limits, which means there are no specific policy options to look at and model the impacts. Alternative policies and the way nutrient limits are allocated will impact on the selection of mitigation options by farmers. Therefore, this study focuses on only one nutrient at a time.

This study does not consider the flow-on effects of mitigation beyond the farm gate, for example the impacts on other industries such as sheep and beef farmers providing wintering services. This will be captured in **The Southland Economic Model for Fresh Water**.

This study uses earnings before interest and tax (EBIT), which includes cash expenses and depreciation. Excluding interest means that all farms are comparable in terms of the mitigation curves; however, it means that farms may appear able to pay for nutrient mitigation when, in reality, once interest is factored in a farm business becomes unfeasible. It also excludes any freed up capital resulting from selling cows and milk company shares (if applicable). The implications of these assumptions and the feasibility of a farm business once debt levels and debt repayment will be relevant in **The Southland Economic Model for Fresh Water**. Consideration will also need to be given to alternative long term milk price scenarios.

The use of two different modelling software tools has led to some factors being considered on a different basis. For example, OVERSEER measures nutrient loss from the whole farm (including effective milking platform, effective support block where applicable, and ineffective area) while FARMAX evaluates operating profit per effective hectare (milking platform and support block where applicable). There is no immediate way to resolve this, and as such, for results per hectare every attempt has been made to clearly identify which hectares they relate to (for example if it is eff. ha or total hectares, or just the milking platform or the milking platform plus support blocks).

The information in this study, and therefore the results, are only as good as the raw data collected. On this note a key message from this study is that farms should ensure accurate, reliable and auditable information is kept for their farm systems in enough detail to create robust OVERSEER files. This will become especially important for farmers when regulations are implemented and Environment Southland monitors compliance.

Given all the limitations of this study, it is the relative economic impact of the various scenarios and the order of magnitude of any impacts that is important. This case study modelling is designed to build a picture of what the impacts of nutrient mitigation might be on a particular farm, it is not designed as a policy scenario.

3.4. Mitigation Results

3.4.1. Stage One Mitigations

Nitrogen Mitigation Results

Figure C49 to Figure C58 show the results of the nitrogen mitigation modelling. They are presented in both percentage and absolute figures for the four FMUs, with Matāura split into north and south groups[19]. Changes in nutrient loss are presented as per total hectares (including ineffective hectares and support blocks where applicable) and changes in operating profit are presented as per effective milking platform hectare. Each line represents a case study farm.

Figure C49 to Figure C53 show the relationship between the percentage reduction in nitrogen leaching and operating profit. The graphs show a significant variation in shape of mitigation curves and cost of mitigation. They also show that there is no overall significant difference between FMUs. Some farms have mitigation curves that flatten out at higher levels of nitrogen mitigation which appears to contradict the assumption of the lowest cost mitigation. However, it is important to remember that the mitigation strategies applied in this work are cumulative and applying the mitigations in a different order may not have the same impact. The curves are also more clustered at the lower levels of nitrogen reduction than at the higher levels of nitrogen reduction.

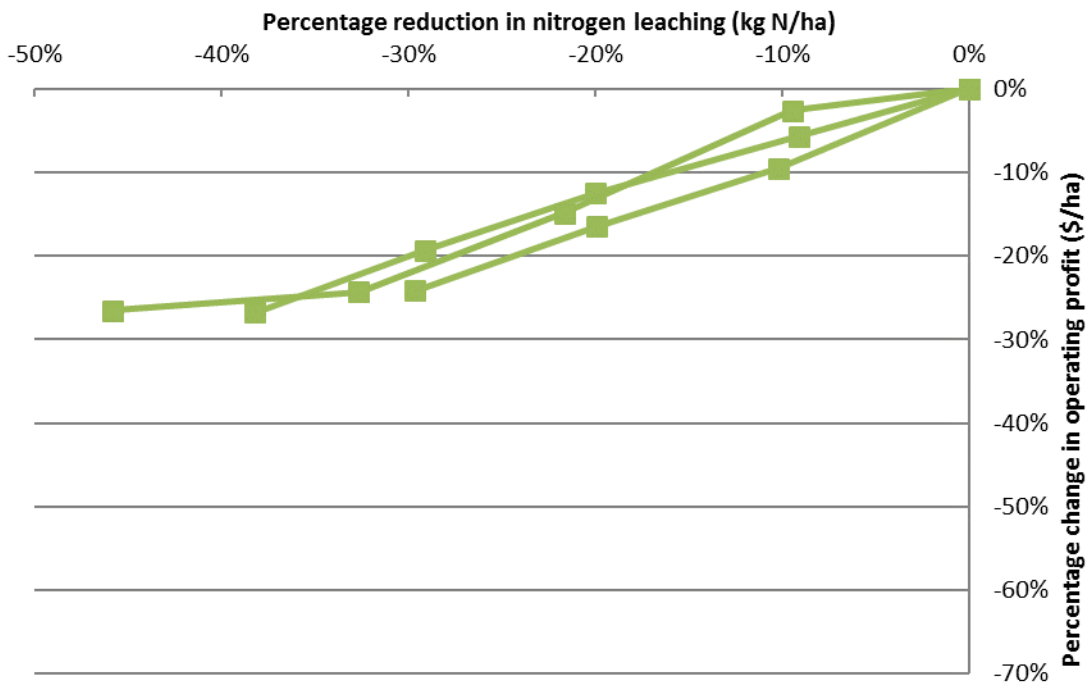

Figure C49: Percentage reduction in nitrogen leaching – Waiau (3 farms)

[19] North and south of Gore.

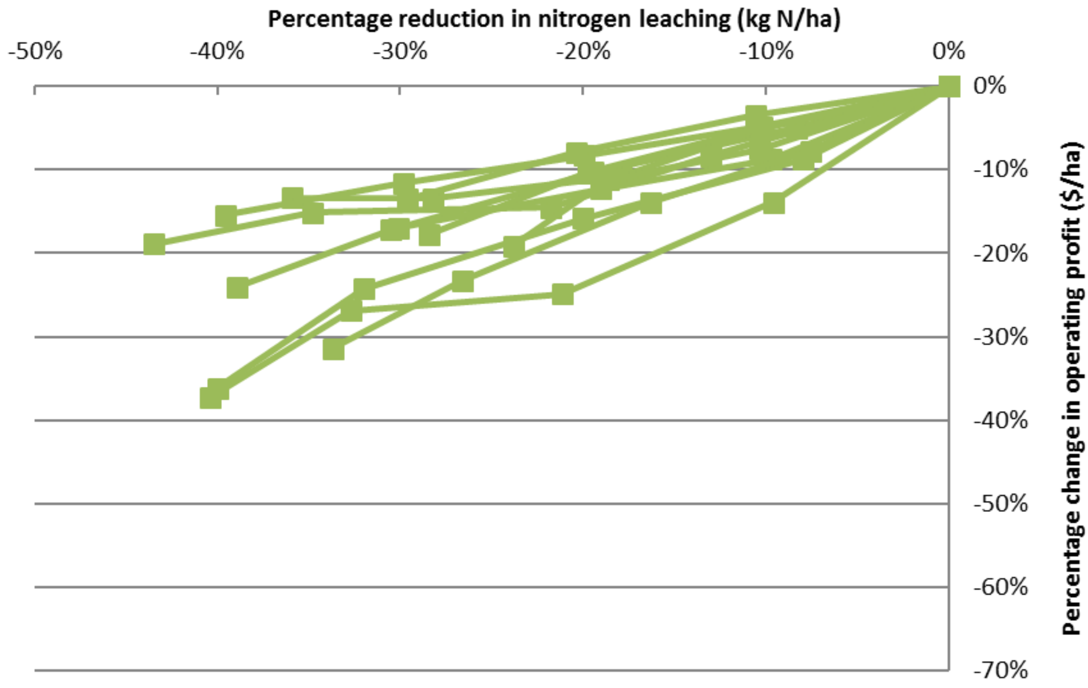

Figure C50: Percentage reduction in nitrogen leaching – Aparima (11 farms)

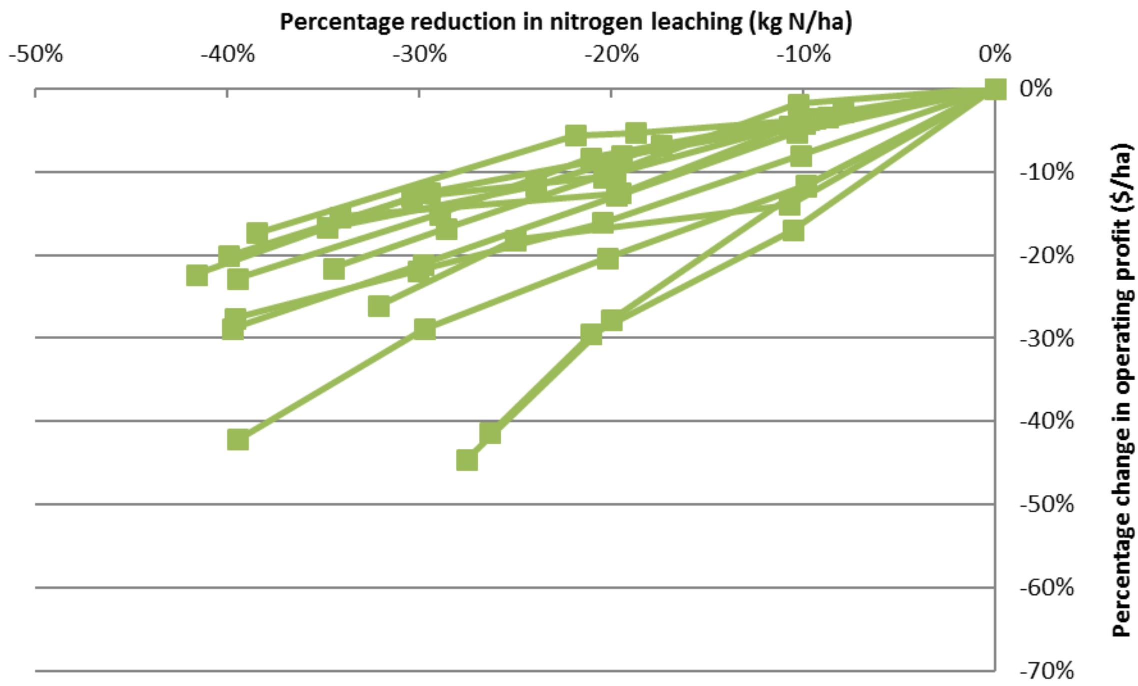

Figure C51: Percentage reduction in nitrogen leaching – Ōreti (13 farms)

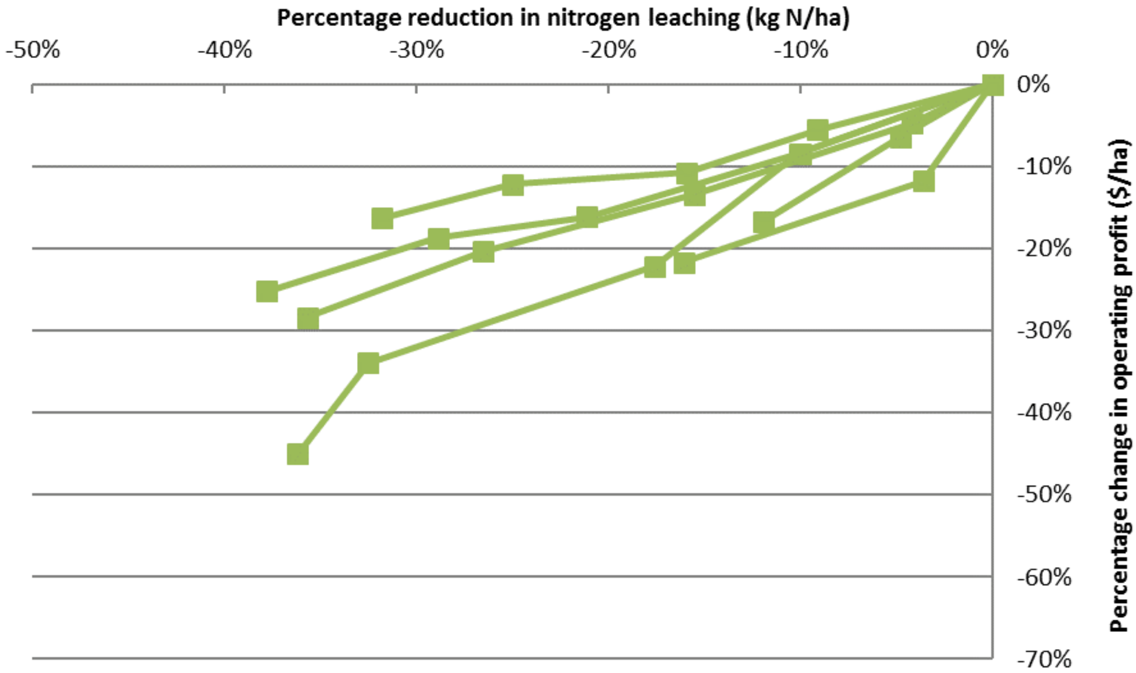

Figure C52: Percentage reduction in nitrogen leaching – Upper Matāura North (6 farms)

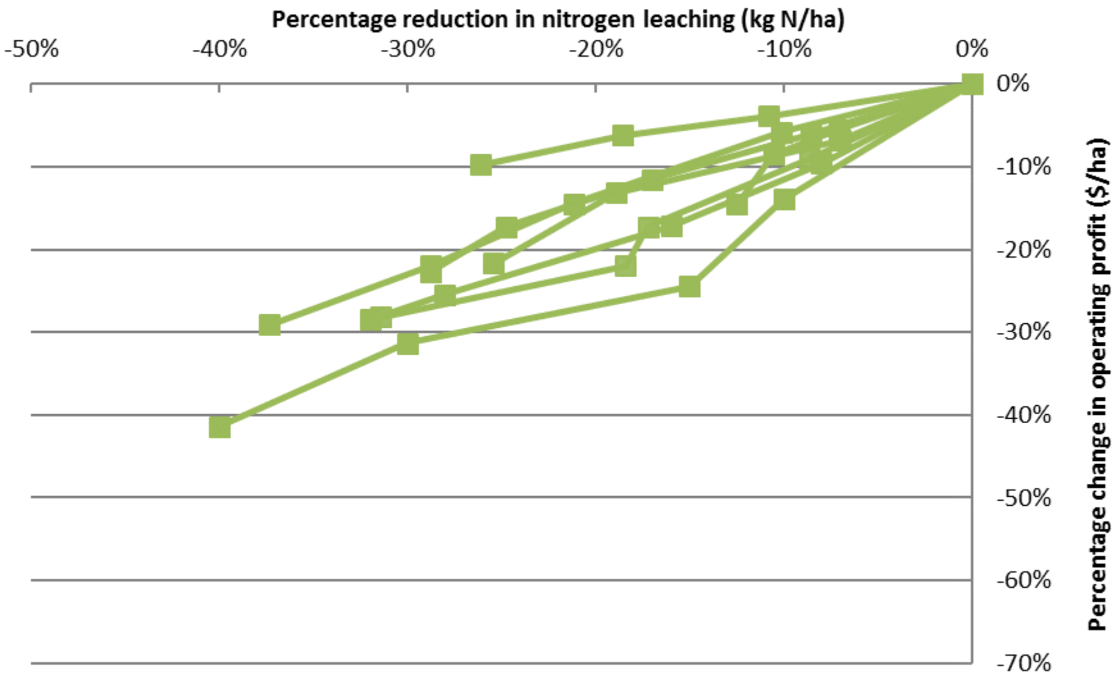

Figure C53: Percentage reduction in nitrogen leaching – Lower Matāura (8 farms)

Figure C54 to Figure C58 show the relationship between nitrogen leaching reduction and operating profit in absolute terms per hectare. These graphs show that no two farms have the same starting position for nitrogen leaching and operating profit per hectare and they are wide ranging. Also, a certain percentage level of nitrogen reduction across the region will result in a different level of nitrogen leaching abated from each farm, a 10% reduction may be minor on one farm (e.g. 1 kg N/ha/year) but significant on another farm (e.g. 10 kg N/ha/year). Likewise, an equal cost in terms of percentage reduction in operating profit will mean a different reduction in actual operating profit per hectare for each farm. These graphs also show no correlation between nitrogen leaching and operating profit.

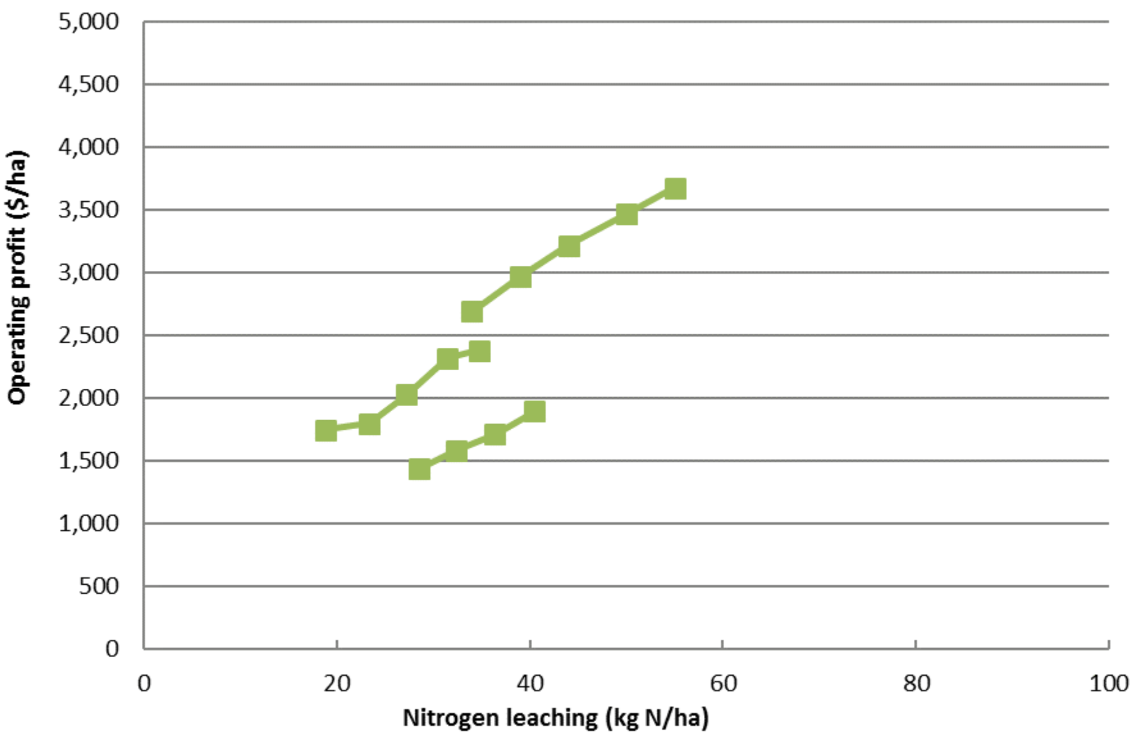

Figure C54: Absolute reduction in nitrogen leaching – Waiau (3 farms)

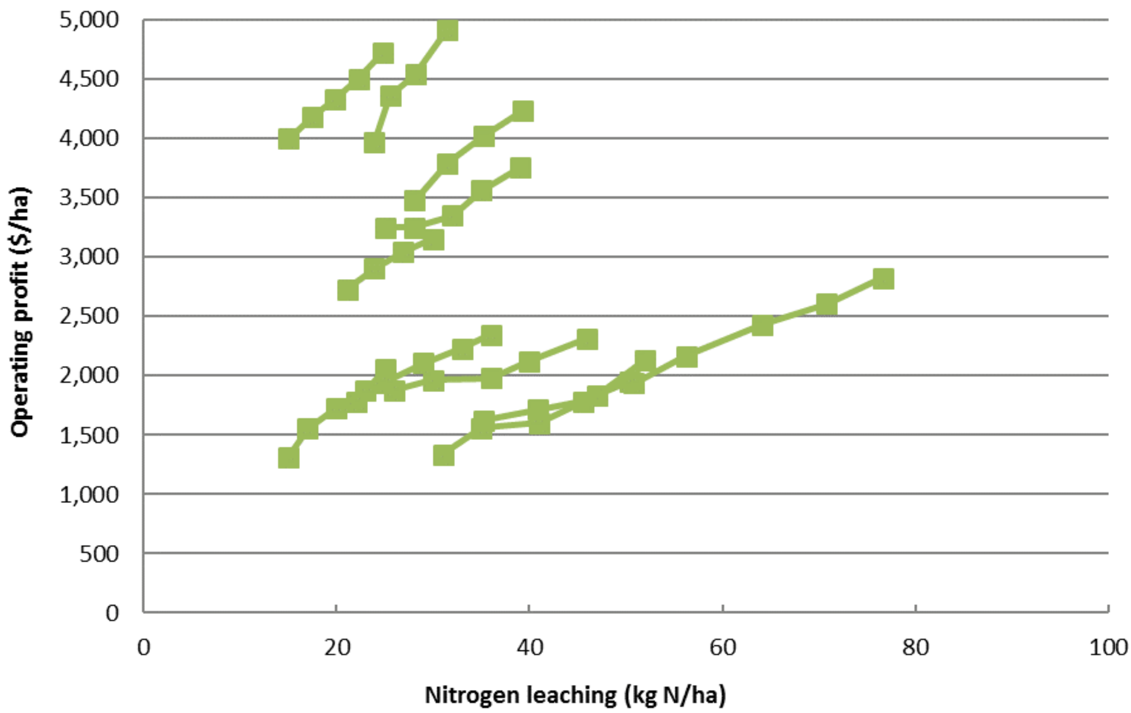

Figure C55: Absolute reduction in nitrogen leaching – Aparima (11 farms)

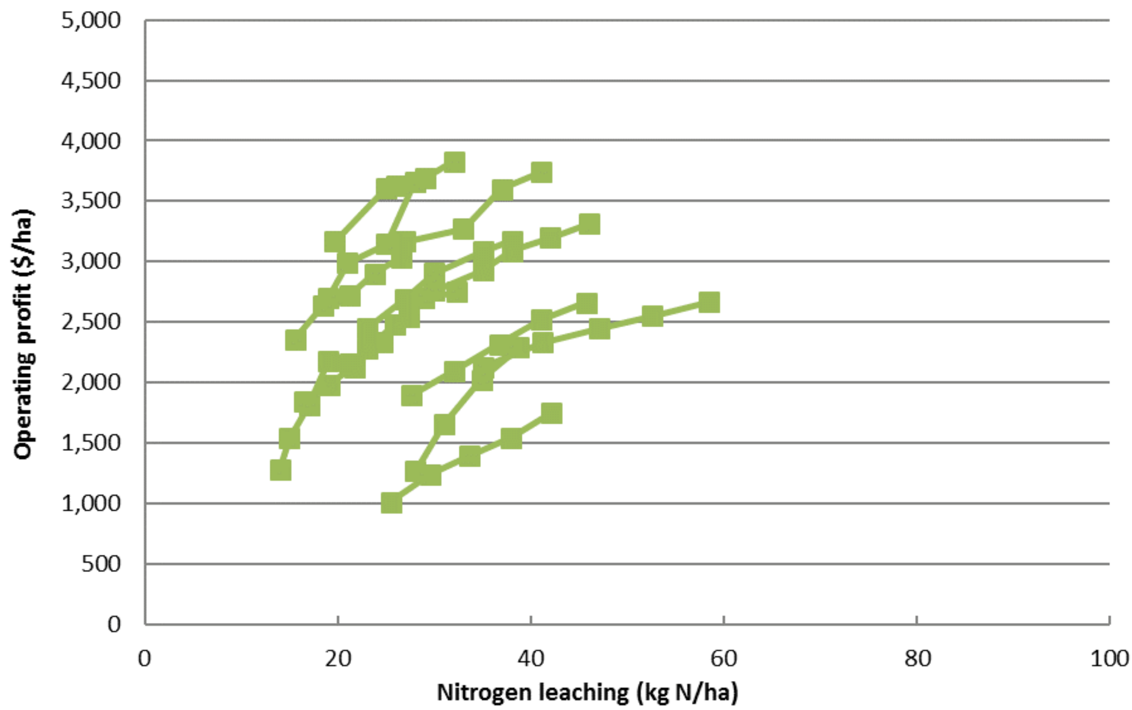

Figure C56: Absolute reduction in nitrogen leaching – Ōreti (13 farms)

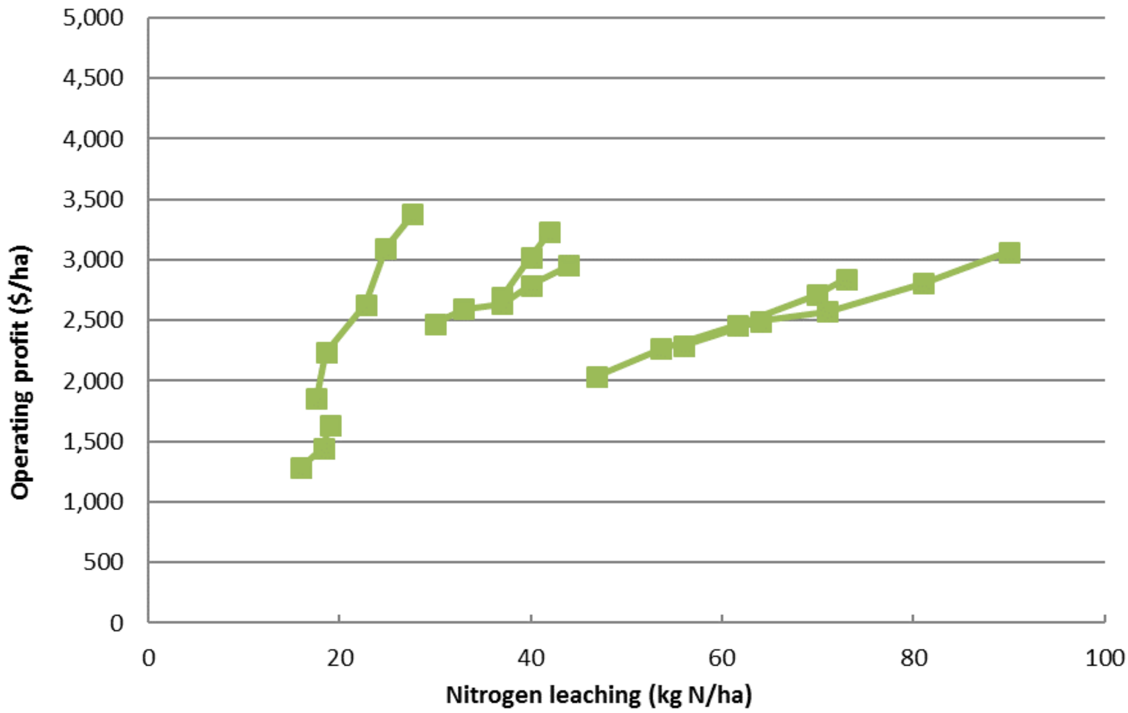

Figure C57: Absolute reduction in nitrogen leaching – Upper Matāura (6 farms)

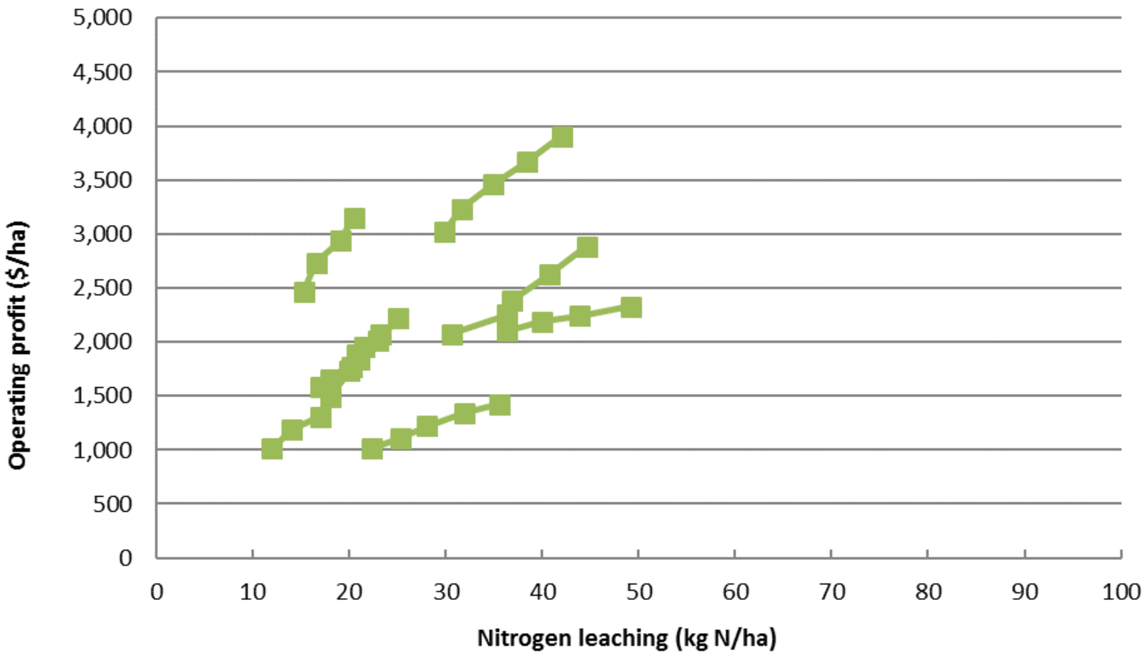

Figure C58: Absolute reduction in nitrogen leaching – Lower Matāura (8 farms)

Phosphorus Mitigation Results

Figure C59 to Figure C68 show the results of the phosphorus mitigation modelling. They are presented in both percentage and absolute figures for four FMUs, with Matāura split into north and south groups[20]. Changes in nutrient loss are presented as per total hectares (including ineffective areas and support blocks where applicable) and changes in operating profit are presented as per effective milking platform hectare. Each line represents a case study farm.

Figure C59 to Figure C63 show the relationship between the percentage reduction in phosphorus loss and operating profit. When compared to the nitrogen mitigation curves, the phosphorus curves have a wider range and are both steeper and shorter, i.e. the farms cannot achieve as large a percentage reduction for phosphorus as they could for nitrogen. Farms that had relatively flat mitigation curves, or were relatively flat for the first proportion of their curve, were suitable for RPR usage or could reduce Olsen P levels to the agronomic optimum. Farms that have steeper curves had neither of these options. On some of the steeper mitigation curves changing to once a day milking milking was a mitigation option.

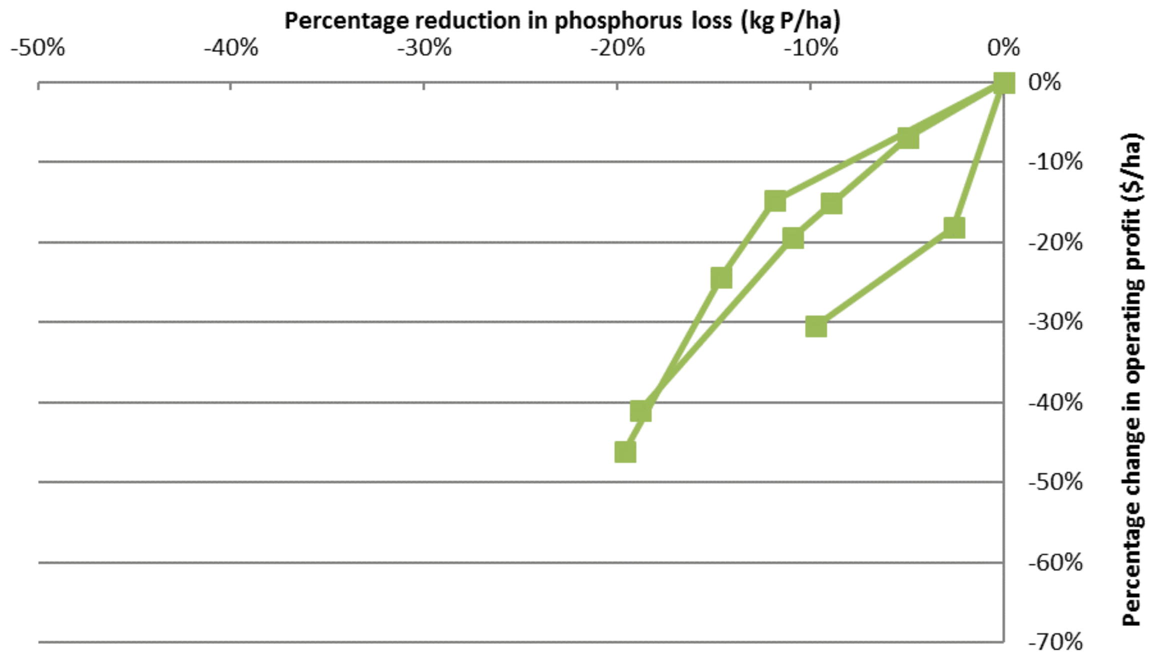

Figure C59: Percentage reduction in phosphorus loss – Waiau (3 farms)

[20] North and south of Gore.

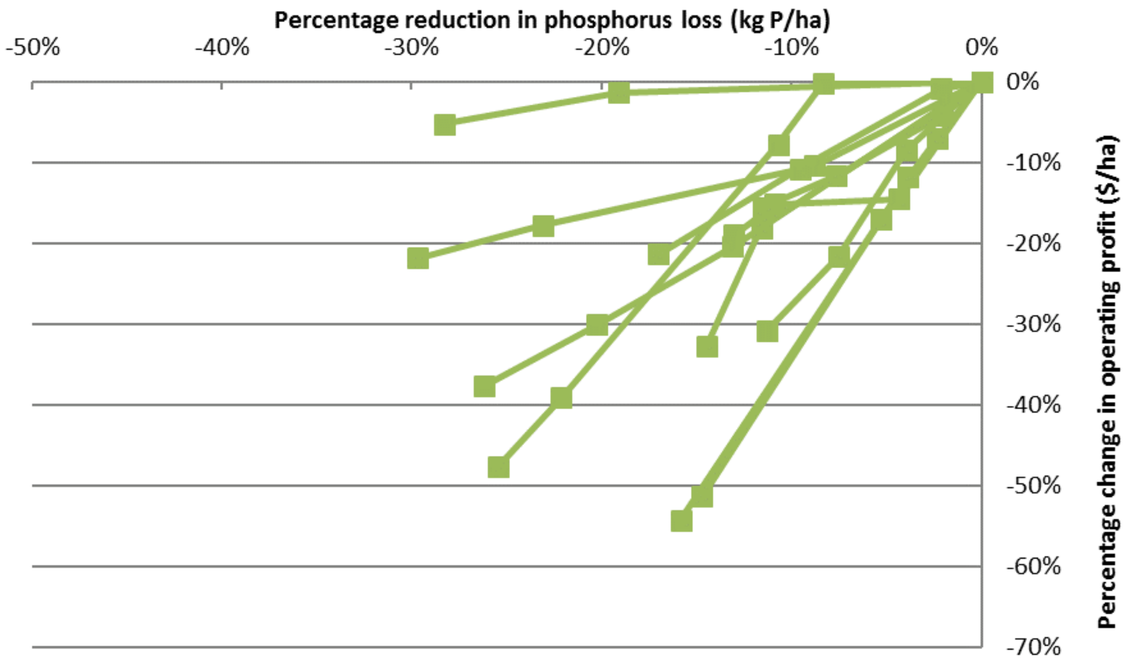

Figure C60: Percentage reduction in phosphorus loss – Aparima (11 farms)

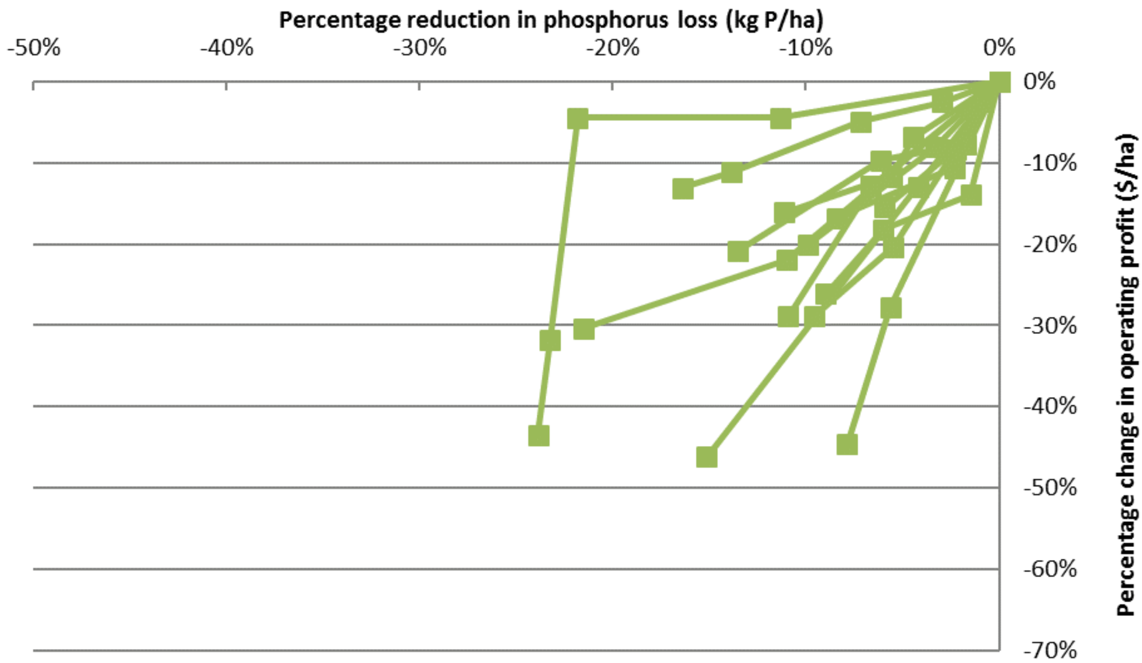

Figure C61: Percentage reduction in phosphorus loss – Ōreti (13 farms)

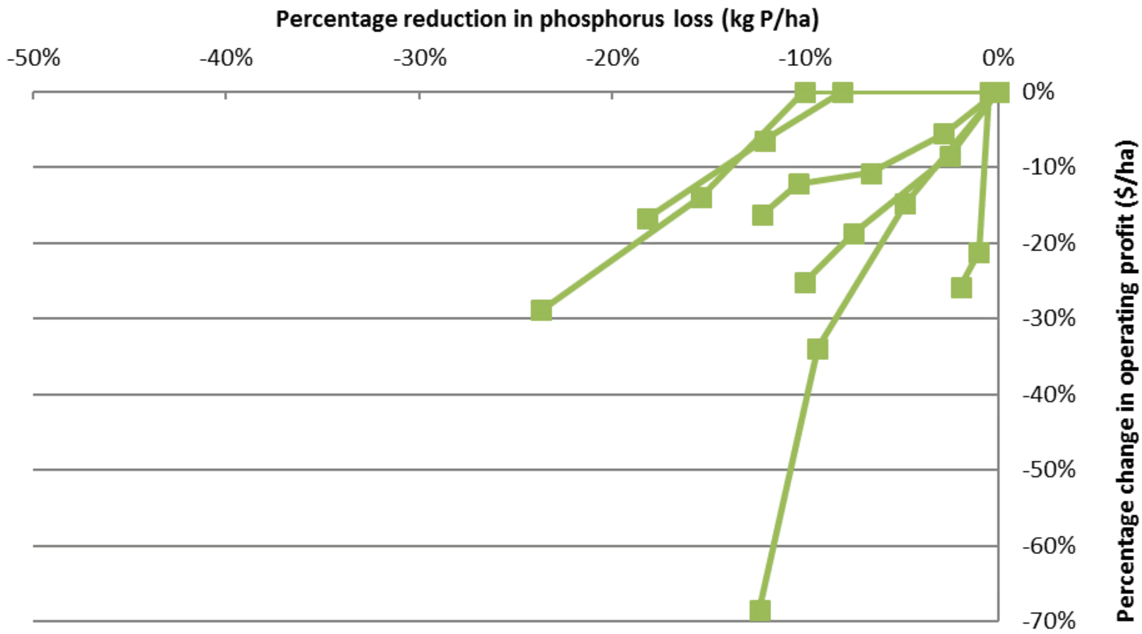

Figure C62: Percentage reduction in phosphorus loss – Upper Matāura (6 farms)

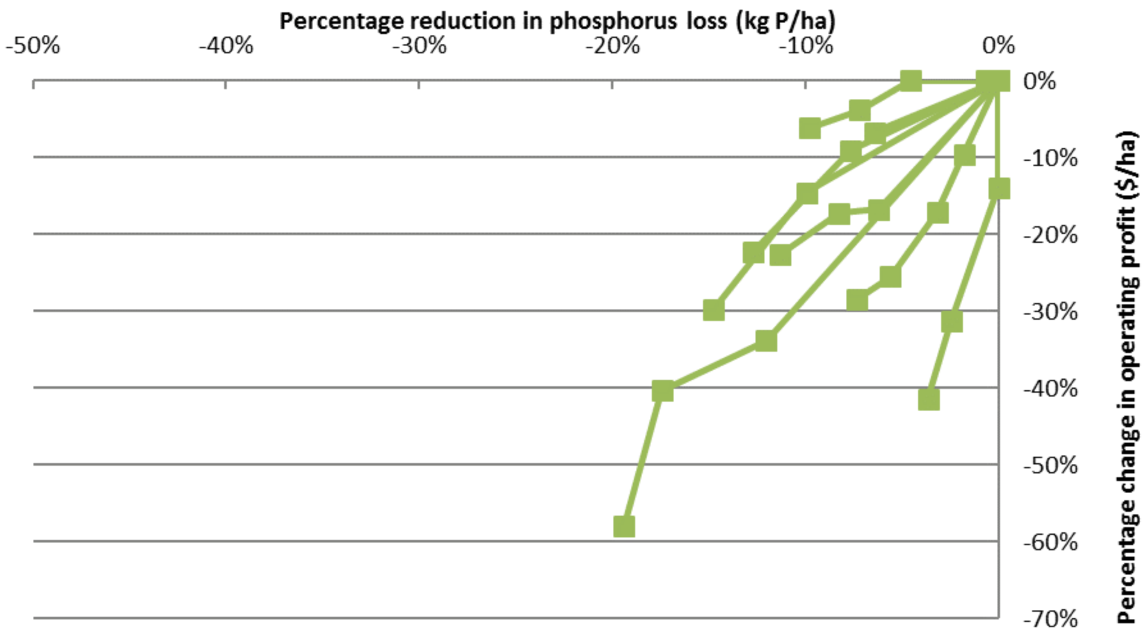

Figure C63: Percentage reduction in phosphorus loss – Lower Matāura (8 farms)

Figure C64 to Figure C68 show the relationship between phosphorus loss reduction and operating profit in absolute terms per hectare. These figures highlight that no two farms are the same. The scale along the horizontal axis is much smaller than that for nitrogen, which indicates that the difference in phosphorus loss per hectare between farms is much smaller. As with the nitrogen mitigation curves, a standard percentage reduction in phosphorus loss or operating profit throughout the catchment will result in every farm having a different impact on the regional estimated nutrient loss and each will incur different costs due to the range in starting positions.

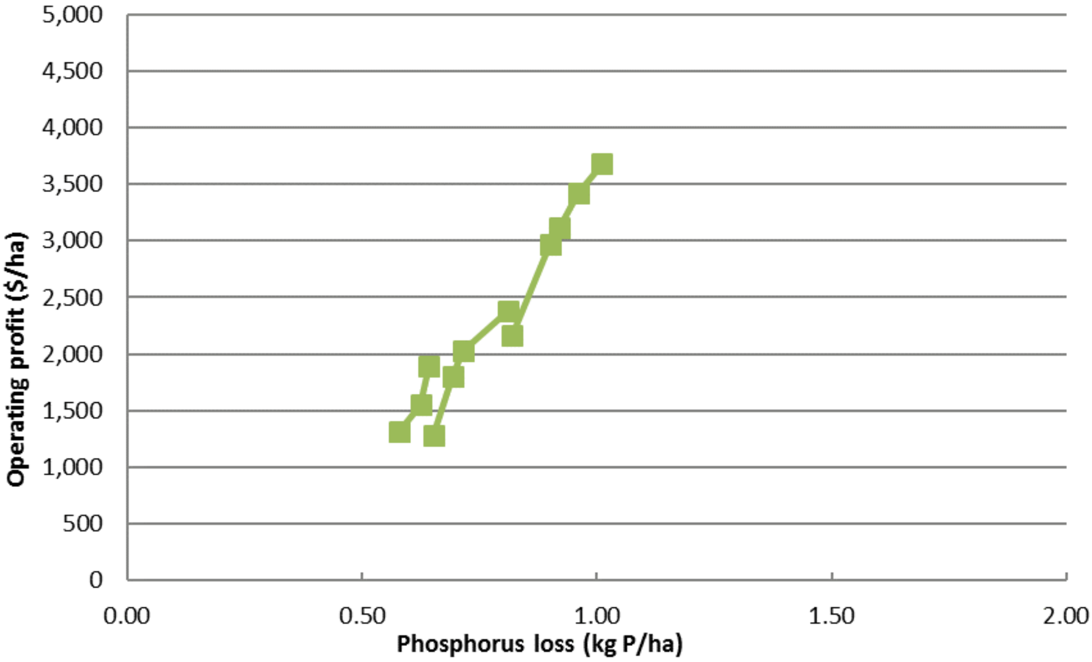

Figure C64: Absolute reduction in phosphorus loss – Waiau (3 farms)

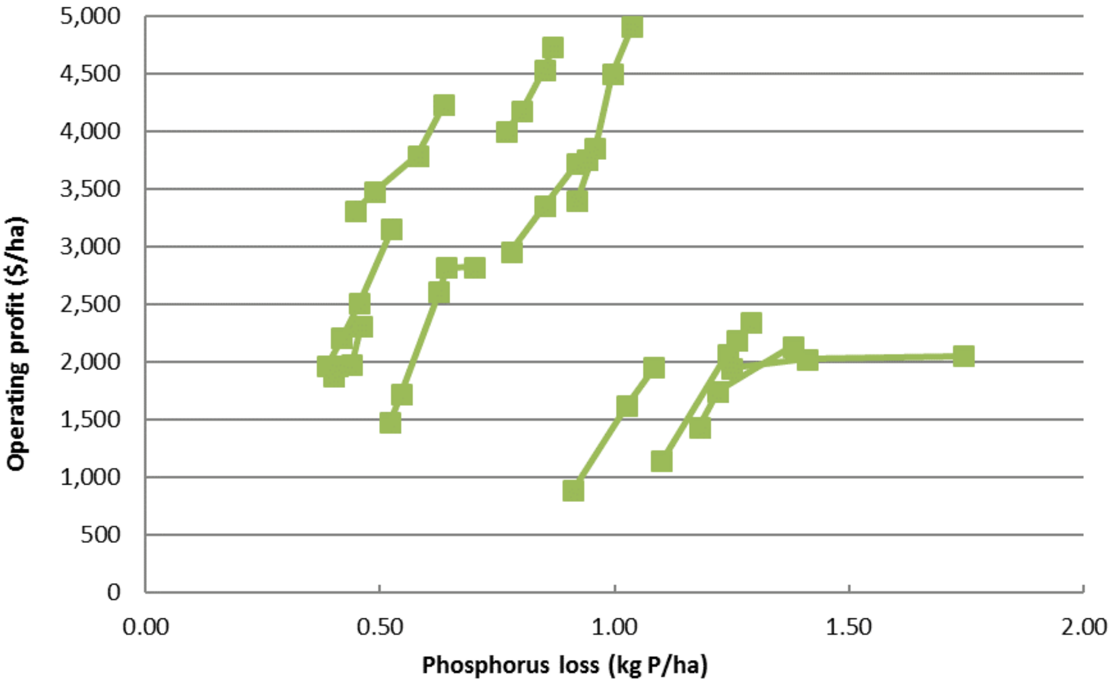

Figure C65: Absolute reduction in phosphorus loss – Aparima (11 farms)

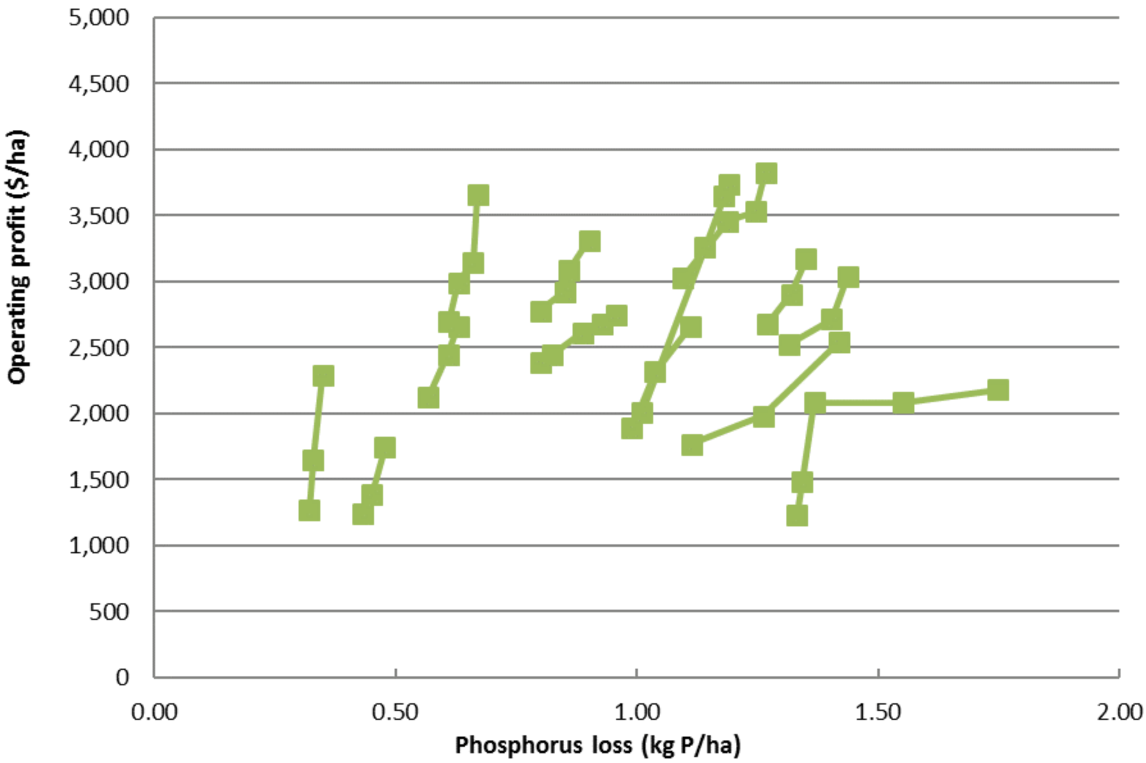

Figure C66: Absolute reduction in phosphorus loss – Ōreti (13 farms)

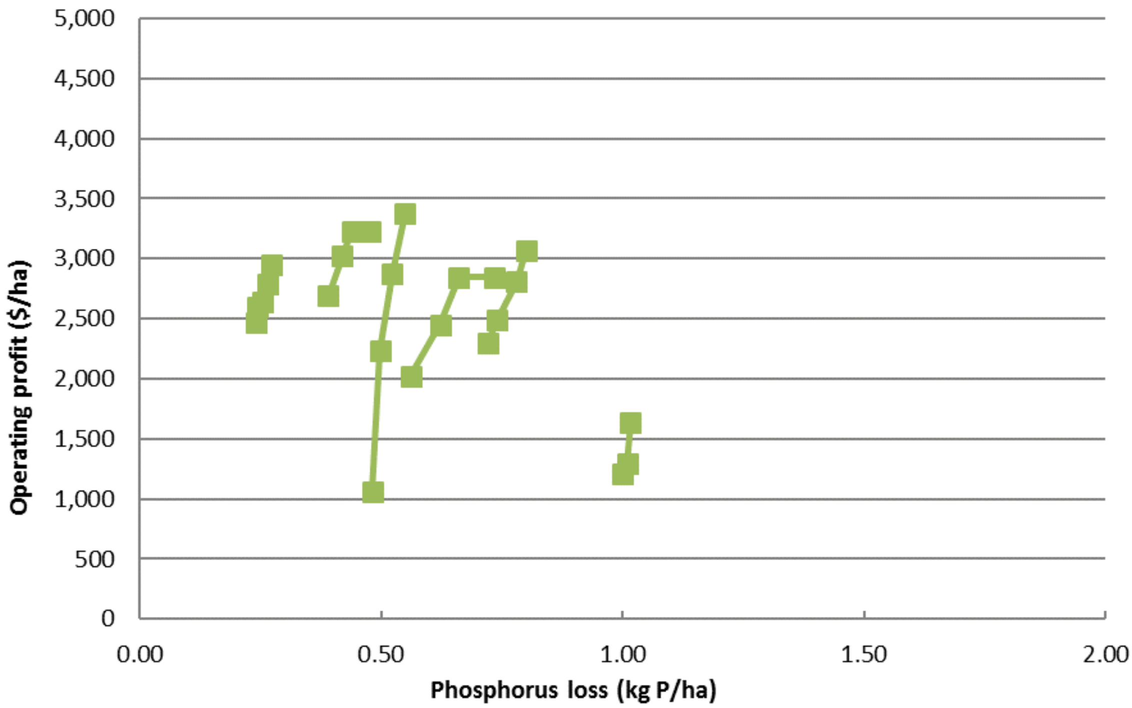

Figure C67: Absolute reduction in phosphorus loss – Upper Matāura (6 farms)

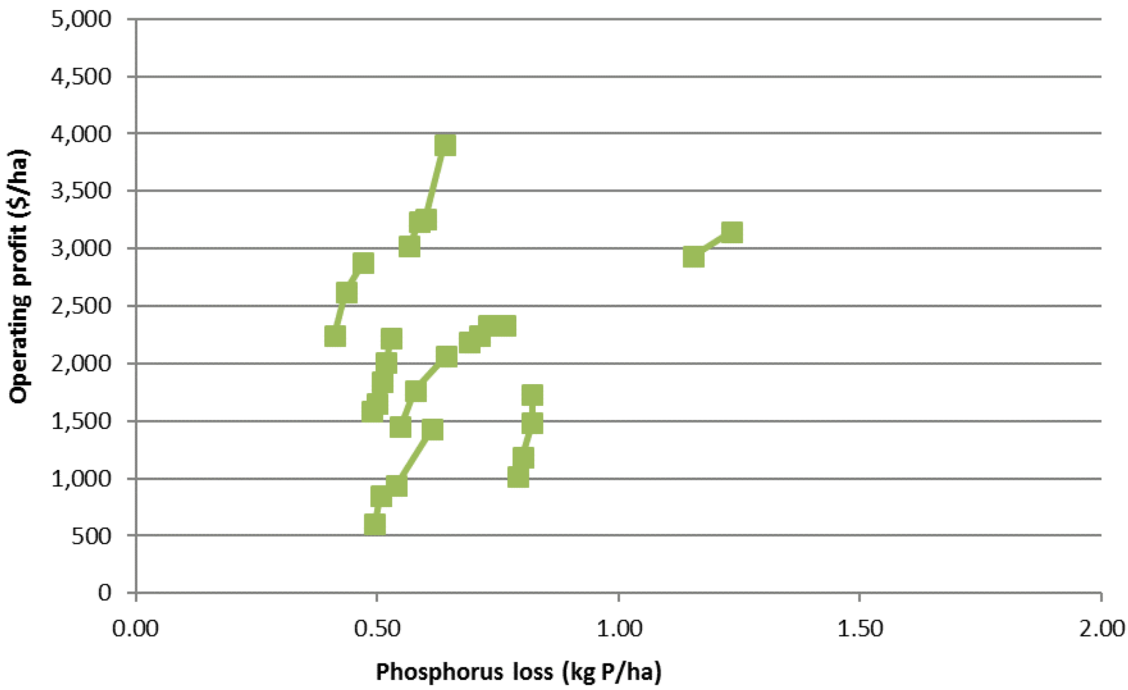

Figure C68: Absolute reduction in phosphorus loss – Lower Matāura (8 farms)

Distribution of Mitigation Costs

The above figures show the individual mitigation costs for each farm within a FMU. It is important to understand the distribution of such costs for each farm. Each farm's mitigations are targeted at a percentage reduction (e.g. 10% reduction in nitrogen); however, they do not always meet the exact percentage. In order to compare distributions of costs the mitigations were interpolated to get the exact costs for the targeted mitigation levels. Once a farm was unable to achieve a certain level of mitigation, modelling was stopped and no further results for that farm were shown, i.e. mitigation costs were not extrapolated beyond the point when a farm had to retire land.

The following two figures (Figure C69 and Figure C70) show the distribution of mitigation costs for each farm for nitrogen and phosphorus. As higher levels of reduction are required, there is generally a larger distribution of costs and it is more expensive. The key indicates how many farms in each sample reached the indicated reduction level. For example 19 farms were able to reach a 15% reduction in phosphorus loss and this reduced the operating profit by between 1% and 54%.

There is no relationship between the farms which can achieve the higher nutrient loss reductions. For example, not all of the lower nitrogen leaching farms drop out of the sample at the higher percentage reductions of nitrogen leaching. Nor is there any particular group of farms that have a higher or lower cost. It is not a particular group of farm input systems, FMU or soil types that have the highest cost or that can reach the higher nutrient loss reductions. This is because it is the interaction of the key drivers of nutrient loss and farm management that dictates the mitigation curve for each farm.

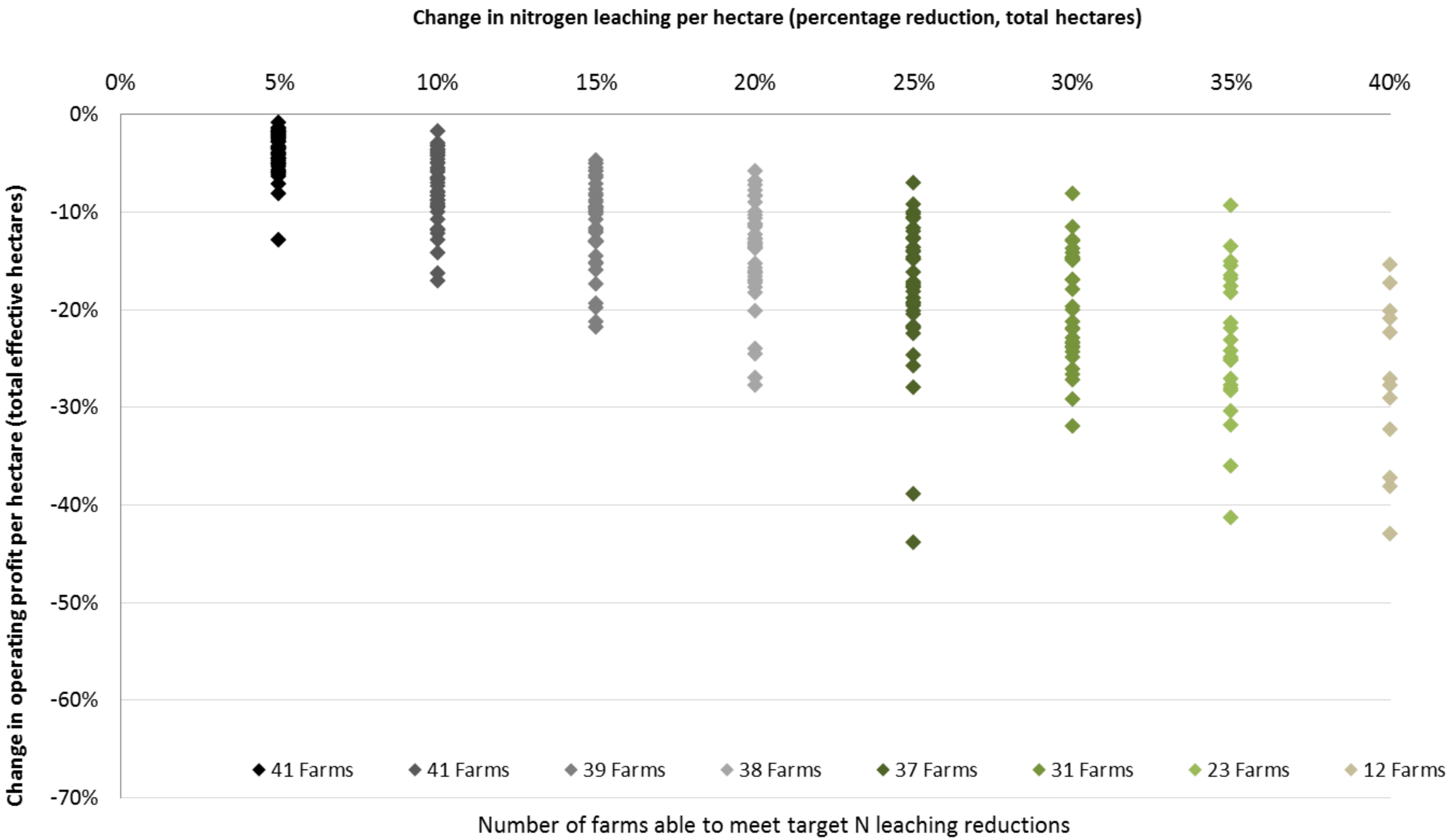

Figure C69: Distribution of nitrogen mitigation cost per farm

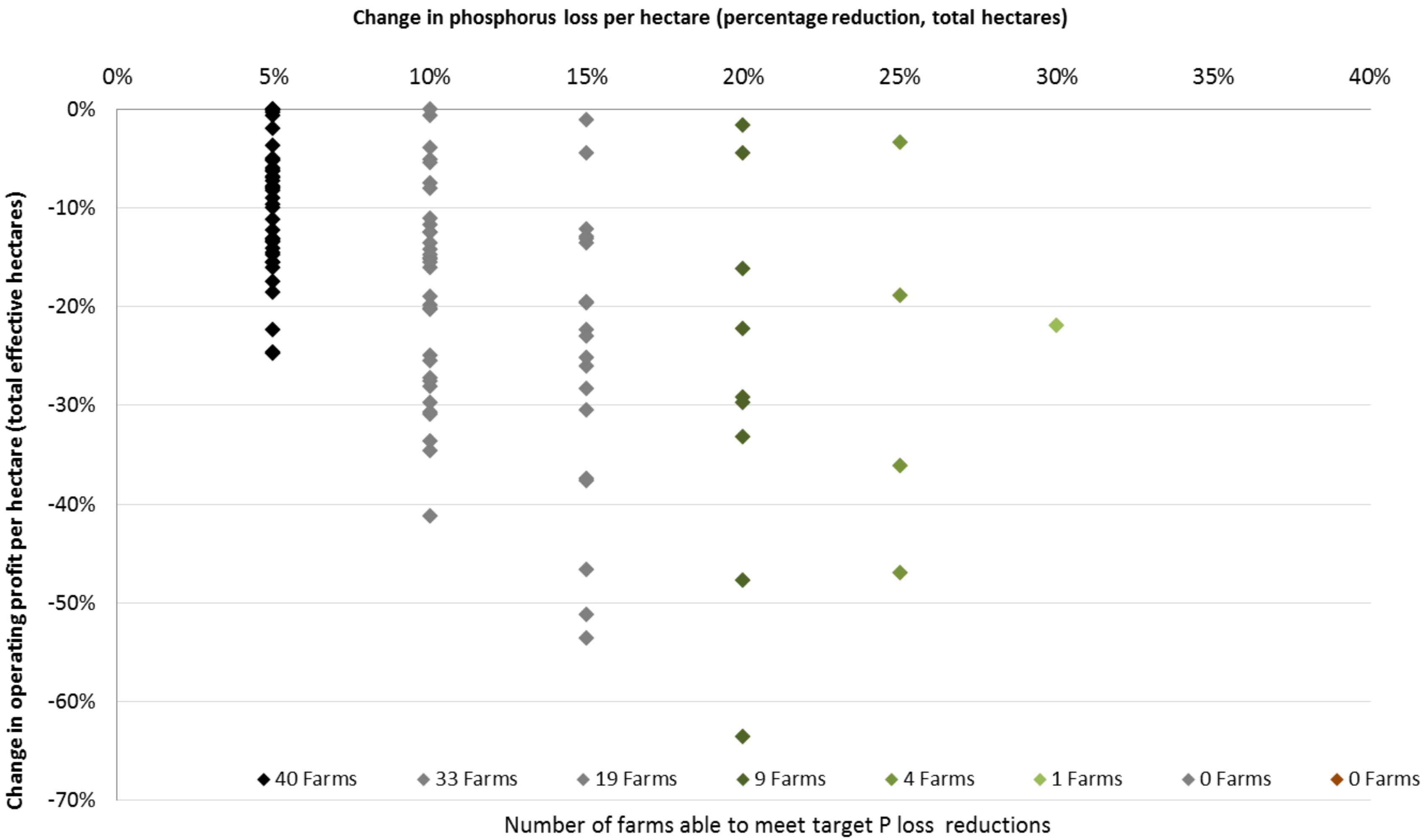

Figure C70: Distribution of phosphorus mitigation cost per farm

Sensitivity Analysis

Two sensitivity analyses were undertaken in relation to this modelling which looked at the effect of the inclusion of interest and rent payments on operating profit, and the change in milk price.

The effect of the inclusion of interest and rent was analysed because a farm can be making a positive operating profit but after paying other costs, namely interest and rent, the profit will be reduced and the business may even be running at a loss. This significantly reduces the ability of farmers to pay for mitigation and in this situation the business is essentially unviable and may be sold, or a land use change may occur. Drawings were not included as wages were adjusted in operating profit to include a management wage and thus including drawings as well would be double counting. Tax was not included as this would depend on the income that was earned but also needs to be considered. However, it is also recognised that a farm also needs to pay tax and allowance needs to be made for capital development.

To calculate this sensitivity analysis, rent and interest costs per hectare were added to operating profit and this was graphed (Figure C71 and Figure C72). The interest and rent costs used were provided by farmers where they were available. If they were not available, rent was set at zero and interest per hectare was randomly generated from a range that was determined as one standard deviation above and below the mean of interest per hectare from the farms that had provided data. Once operating profit is used to pay other obligations, such as interest, there is significantly less operating profit remaining to allocate to mitigating nutrient losses.

The change in milk price was calculated by altering the milk revenue received. Costs were left unchanged, but it is likely that farmers would alter their on-farm decisions in response to changes in the milk price. However, this assumption allowed a comparison of the same mitigations at a lower milk price. Changing decisions on farm would also change the nutrient losses and the mitigation curves would no longer be comparable. There was no available information demonstrating how a farmer would change their on-farm decisions in response to changes in the milk price at the time of modelling.

A different milk price significantly influences the ability of a farm to pay for mitigation. This is particularly relevant in an industry experiencing increased volatility in milk price, especially if chosen mitigation options require capital investment. This sensitivity analysis shows a break-even milk price (given the farmers' decision making in the 2013-14 season) of approximately $5.75 per kilogram of milksolids. This analysis indicates that while mitigation may be possible in some years, it may mean some farmers are unviable in other years and this could have large implications, including a requirement for increased overdrafts to survive some seasons.

Figure C71 and Figure C72 show an example of the sensitivity analysis undertaken for each case study farm with separate graphs for nitrogen and phosphorus. In this example the interest and rent costs were more than the $1 increase in milk price. If the milk price is reduced to $5.50 per kilogram of milksolids and interest and rent is included, the farm is not making any profit and would be unlikely to undertake the mitigation.

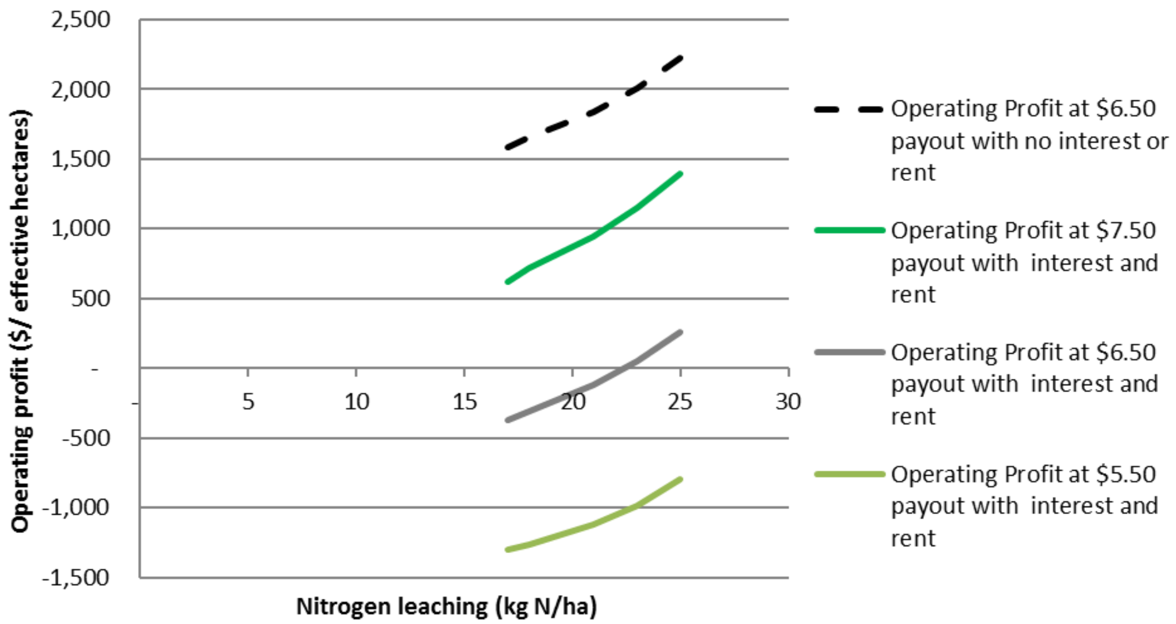

Figure C71: Nitrogen sensitivity analysis, case study farm

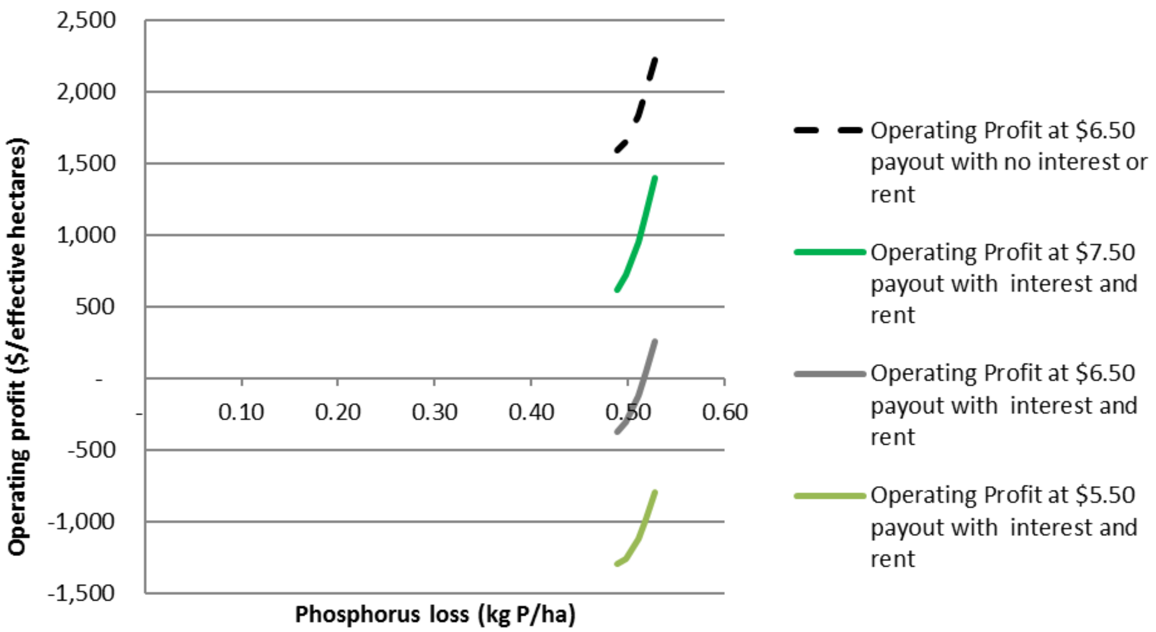

Figure C72: Phosphorus sensitivity analysis, case study farm

3.4.2. Stage Two Mitigations

Following the stage one mitigations for nitrogen and phosphorus, more targeted and specific mitigations that have a large impact on farm systems and/or a large capital cost were considered. The stage two mitigations that were considered were: barn construction, wetland creation, gibberellic acid applications, installation of grass filter strips and significant changes in effluent storage and disposal.

Wetlands and Grass Filter Strips

Wetlands and grass filter strips were not modelled. This was due to the complexity of modelling mitigation strategies that are very specific to each farm. For example, a wetland or grass filter strip will have a differing: set up, cost for set up and maintenance, and level of effectiveness on each farm.

Hypothetical wetlands and grass filter strips are extremely complex to set up in OVERSEER as they require a large number of inputs which would have to be assumed, including the following:

1. Effective wetland area,
2. Wetland condition (based on flow path length to width ratio, vegetation and potential for flow channelization and dead-zones),
3. Wetland type (based on wetness throughout the year, vegetation and potential stock effects),
4. Catchment area,
5. Catchment convergence (the measure of the percentage of shallow runoff, surface and sub-surface drainage that flow into a wetland relative to direct flow), and
6. Aquitard depth (the depth down to the soil layer that is impervious to water, or where soil drainage is very slow).

The values entered for the above variables will be specific to each farm and making assumptions will reduce the certainty of the mitigation effectiveness. In addition, it may be challenging to find an obvious area suitable for wetland construction. No two wetlands will be the same in their construction and management, so it is not possible to accurately estimate the associated costs for fencing, planting and resource consent on each farm. In addition to this modelling difficulty, there is some uncertainty regarding the effectiveness of artificial wetlands in being a long term mitigation option. Some constructed artificial wetlands in Waikato, Northland and Southland have shown little to no uptake of phosphorus (Sukias, Tanner, & Stott, 2006). Other studies show greater concentrations of dissolved phosphorus exiting a wetland than entering it (Tanner, L, & Sukias, 2005). It has also been found that wetlands may be sinks or sources of phosphorus and are subject to change over time (Reddy, Kadlec, & Gale, 1999). Wetlands remove nitrates via microbial denitrification supplemented by plant uptake and accretion in sediments (Tanner, Hughes, & Sukias, 2013). The ability to remove nitrates depends on factors such as type and construction of the wetland. This does not necessarily mean that the construction of artificial wetlands will not be a successful mitigation option, but it does indicate that certain environments may be better suited than others and that there is limited evidence available regarding the predicted reduction (if any) in nutrient loss. Therefore, as it is relatively unfeasible to model artificial wetlands on farms, due to their highly contextual nature, or predict the expected impact on nutrient loss, they were not included in the modelled stage two mitigations.

Grass filter strips are only applicable in OVERSEER if a farm does not have artificial drainage on a block. To set up hypothetical grass filter strips in OVERSEER the following information needs to be assumed:

1. Dimensions (including catchment area, length and width of strip),
2. Strip condition (including age of strip and entry condition), and
3. Hydraulic performance (including proportion of surface flow that drains through the strip, the proportion of this run off that interacts with the strip and the length of strip that ponds water upslope).

As with wetlands, the values entered when setting up a grass filter strip in OVERSEER dramatically influence its cost and effectiveness as a mitigation strategy. Grass filter strips in OVERSEER are not riparian planting on stream banks: they are an area fenced off containing dense grass such that runoff water passes through it before reaching a water body such as a stream[21]. There are no requirements on what type of fencing is used and therefore the cost will vary across farms based on farmer preferences and farm topography. The information in OVERSEER states:

> *"Defining the effectiveness of a grass filter strip requires observation of how the strip operates during a runoff event. After making these observations, complete the fields provided on this page. Note that a grass filter strip near a stream could be a source of P. In this case P removal by the grass filter strip may be over-estimated due to no recycling of accumulated P and P bypassing the filter strip as re-emergent saturated flow".*

This indicates that the fields required will be hard to estimate for a hypothetical scenario and that grass filter strips could be a source of phosphorus in some cases. While grass filter strips may be a valid mitigation on farm, to model a hypothetical grass filter strip is subject to such uncertainty it was not included in this study.

Gibberellic Acid

Gibberellic acid (GA) is a plant growth promoter naturally produced by plants in warmer months, and applying it in cool weather increases pasture growth. GA provides an opportunity for increased pasture production at either end of the dairy lactation season when pasture growth is typically low. The benefit of GA as a nitrogen mitigation tool is through its use to replace nitrogen fertiliser applications (Ball, Parsons, Rasmussen, Shaw, & Rowarth, 2012). The use of GA requires knowledge about how to integrate it into the farming system without any negative side effects (Bryant, 2014), and there is also a cost associated with purchase and spreading. When using OVERSEER and FARMAX, the way to model GA is to increase the response rate to fertiliser in FARMAX and reduce the volume of fertiliser applied in FARMAX and OVERSEER. In this study GA was modelled on one case study farm, the results are only presented for nitrogen as GA does not impact on phosphorus mitigations (Figure C73).

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[21] OVERSEER

The results of adding GA to the mitigations showed that there was very little additional benefit (Figure C73). Initially it can reduce nitrogen loss at a slightly lower mitigation cost; however, there is a limited benefit from GA if a farm has to reduce over 15% of nitrogen leaching. This is because GA is most effective in autumn and spring and once it is applied changes are still required, such as reducing the stocking rate, in order to get significant reductions in nitrogen leaching. It is also important to consider the margin of error in OVERSEER and FARMAX modelling when looking at minor differences between these two scenarios. While this may be a useful tool to help mitigate nitrogen leaching on some farms, it is unlikely to significantly alter the mitigation curve.

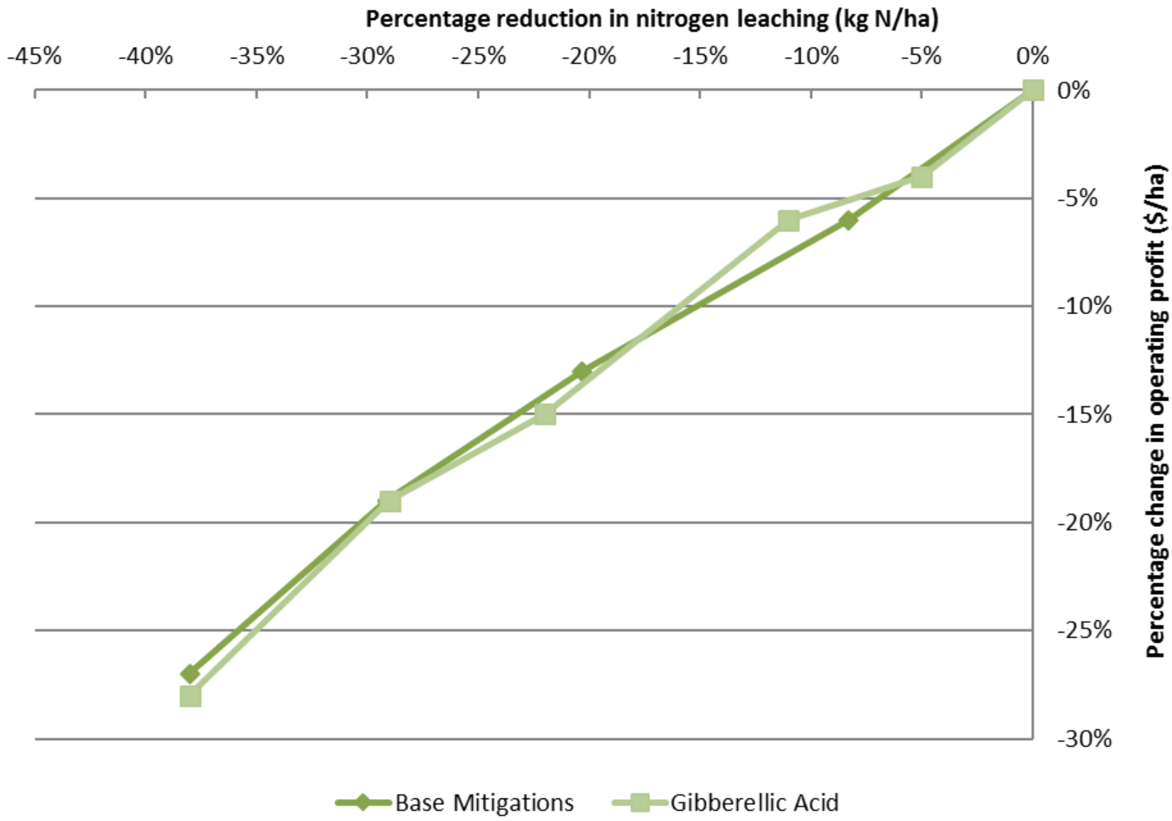

Figure C73: Percentage reduction in nitrogen leaching with gibberellic acid- case study farm

Effluent

On one case study farm the effluent area was increased. This farm was spreading effluent over 50 hectares in the base file which meant it was applying 186 kg N/ha from effluent. This is above the regional council rule of 150 kg N/ha from effluent. This case study farm was on 100% gley soils. When the effluent area was extended to 58 hectares (so 150 kg N/ha of effluent was applied) as part of the first mitigation there was no significant difference in the mitigation curves for nitrogen or phosphorus. This is because the slight increase in cost associated with extending the effluent area was offset by applying slightly less nitrogen fertiliser. The cost of increasing the effluent area was associated with additional piping but not a larger pump given the small increase in size. Fertiliser savings were based on changing the new effluent block to the fertiliser regime of the existing effluent block, and then adjusting both of these to ensure the same kilograms of nitrogen was applied in total through effluent and fertiliser.

When the effluent area was extended significantly to 202 hectares, 80% of the effective milking platform, there was an impact on nitrogen and phosphorus loss. This was possible given the single soil type present on the farm and the flat topography. The extension was included as part of the first mitigation and fertiliser was adjusted accordingly. The capital cost of extending the effluent area was approximately $80,000[22], and included a new pump, hydrants and pipe. The capital cost was assumed to be borrowed at a 6% interest rate and depreciation was 8.5%. Depreciation and interest were included in the mitigation curves; however, the capital cost repayment was not (Figure C74 and Figure C75).

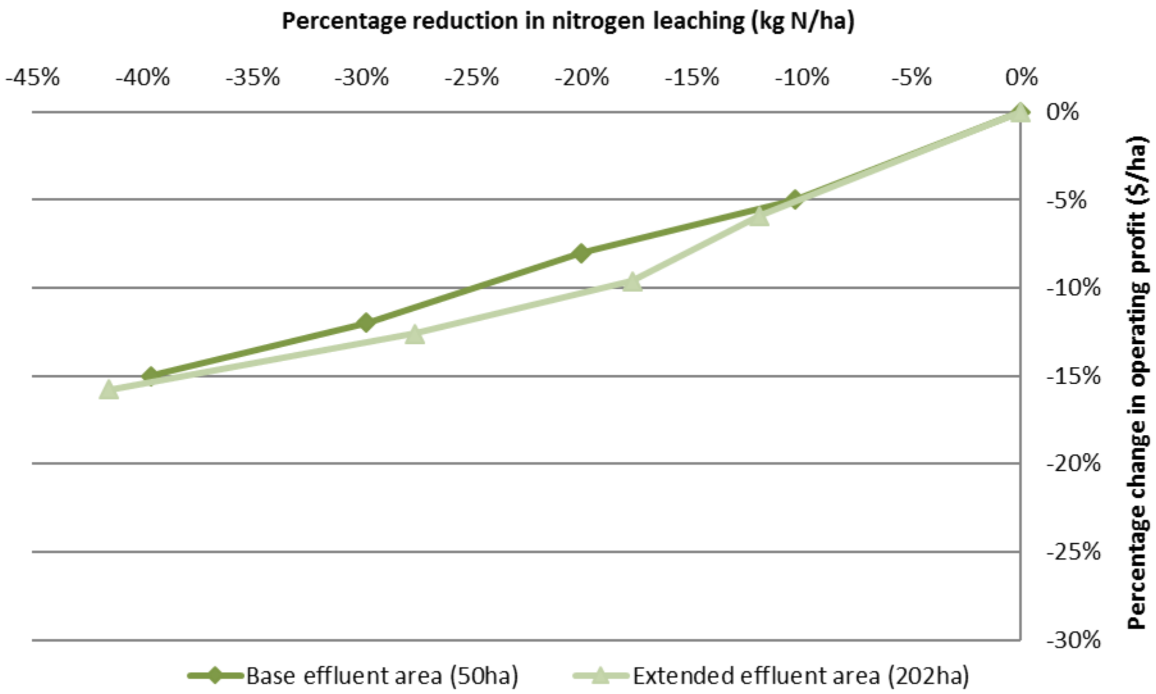

Figure C74: Percentage reduction in nitrogen leaching with increased effluent area- case study farm

[22] DairyNZ Economics Team, Lincoln University Farm Budget Manual, DairyNZ effluent specialists

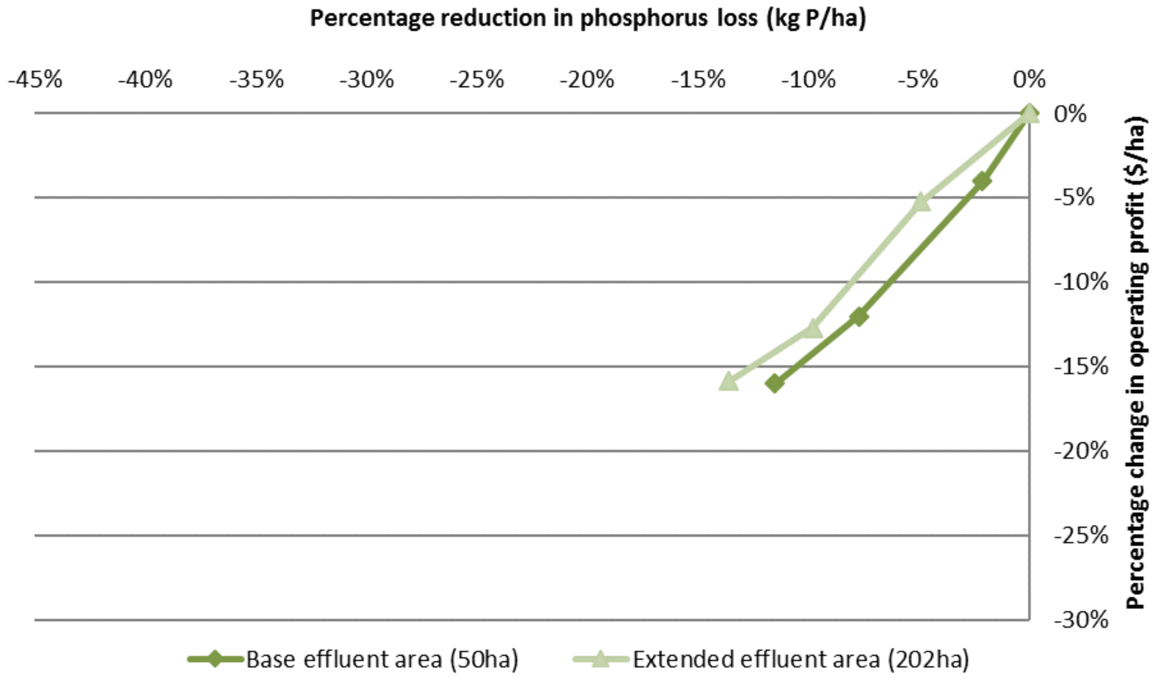

Figure C75: Percentage reduction in phosphorus loss with increased effluent area - case study farm

Figure C74 and Figure C75 show that significantly extending the effluent area on this farm was not the lowest cost nitrogen mitigation option. Figure C75 shows that for phosphorus when the capital repayment was excluded, it was a lower cost than the alternative mitigations for phosphorus loss. The effectiveness of this mitigation will vary farm by farm based on current effluent practices and the availability of a suitable area to extend effluent disposal to.

Barns

There are a range of off pasture structures that can be incorporated into a farm system, including uncovered feed pads, wintering pads and various types of barn systems including free-stall, Herd Homes and covered sawdust barns. The environmental benefits of these come from capturing nitrogen from urine and dung, better feed utilisation and reducing damage to pastures and soils when wet. Restricting grazing to eight hours a day over the autumn/winter period, without supplementary feeding, has been shown to have no impact on production but has the potential to reduce nitrogen leaching by 15-20% (DairyNZ Ltd., 2014). However, intensification of the farming system as a result of these structures can erode the aforementioned environmental benefits. These structures have a significant financial cost, although the dollar amount depends on the type of structure created (Monaghan, 2014). Their ability to mitigate nutrient loss therefore depends on how they are incorporated into the farming system. They are also likely to provide different benefits depending on the farm: the benefit will be greatest on farms with high nutrient loss risk.

Given that a barn can be incorporated into a farm system in a considerable number of ways, it is challenging to model a hypothetical scenario. Instead, it is preferable to look at farms who have incorporated a barn into their farm system and who have records for the pre-barn scenario so a comparison can be made between the environmental situation pre- and post-barn. It is also necessary to look at the net present value of a barn, not just operating profit, given the significant capital costs of barns. Based on these factors, this study did not have the required information in order to robustly model barns as a mitigation option. Instead it draws on an existing study (*Economic and Environmental Analysis of Dairy Farms with Barns* conducted by DairyNZ in May 2015 (Journeaux & Newman, 2015)[23]) that has undertaken this work on two case study farms in Southland (Figure C76 and Figure C77).

The DairyNZ study, *Economic and Environmental Analysis of Dairy Farms with Barns,* was conducted in OVERSEER version 6.1.3 and did not include support blocks. In both cases, after the barn and associated system changes, nitrogen leaching and phosphorus loss increased. This is likely to be because both Southland case study farms intensified their farms after building a barn by increasing cow numbers by approximately 5%, more than doubling supplementary feed per cow, increasing production per cow by 10-20% and lactation length by 3 weeks. The two Southland case study farms in this study had a cost of over $2,000 per cow for their barns and a total cost of capital (including barns and shares and machinery etc.) of over $3,000 per cow. Southland case study Farm 1 had an internal rate of return of 10%, while case study Farm 2 had an internal rate of return of 4%. This indicates that one of the case study farms was providing a return at an 8% discount rate and one was not.

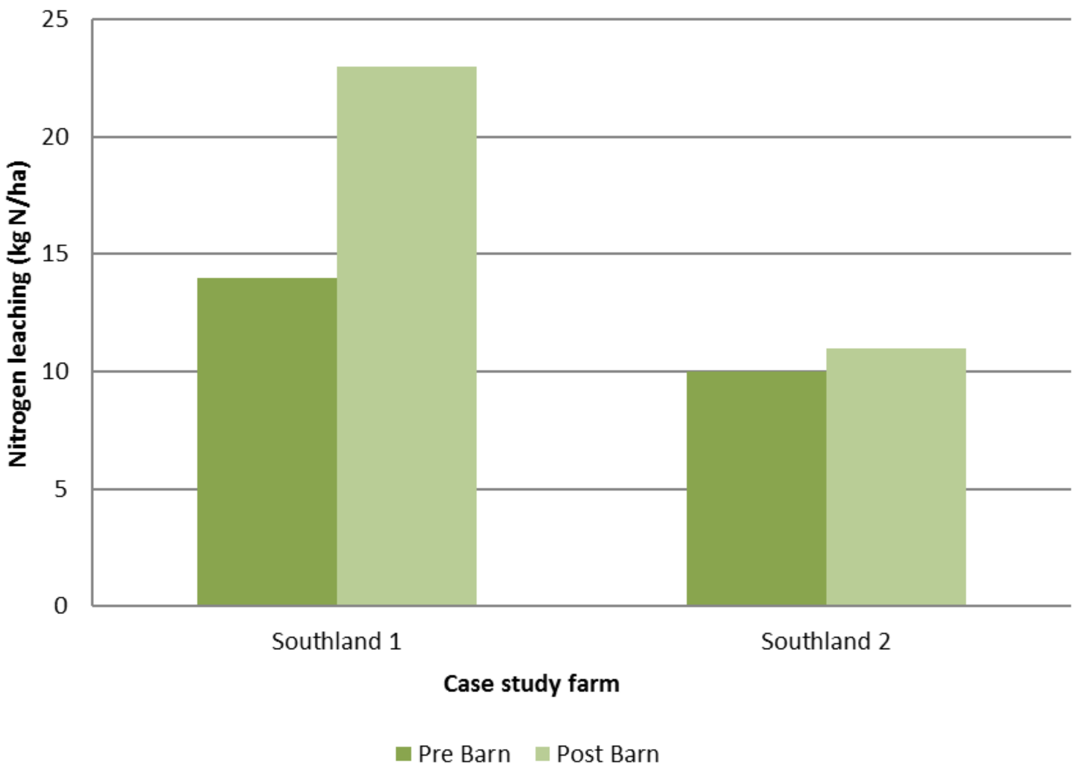

Figure C76: Nitrogen leaching pre and post barn

[23] http://www.dairynz.co.nz/media/3215212/economic-analysis-wintering-barns-report.pdf

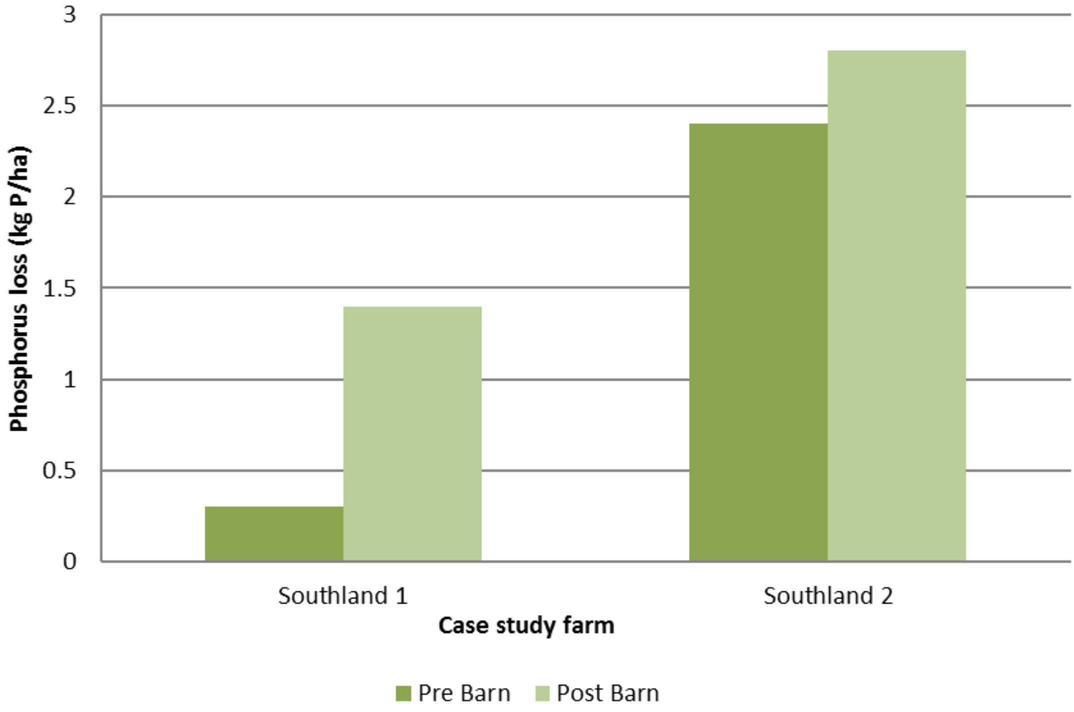

Figure C77: Phosphorus loss pre and post barn

3.5. Summary

The dairy sector's growth in Southland over the past 25 years has been significant. This has increased the contribution the dairy sector makes to the local economy through employment, milk production, transportation and manufacturing. Communities have also benefited from increased dairy with the flow-on expenditure to supporting industries and service providers. However, dairy is reasonably intensive and nitrogen losses modelled through OVERSEER tend to be higher from dairy farms than many other land uses.

The objective of **The Southland Economic Project** was to help inform Environment Southland of the economic impacts of reducing nutrient losses as they develop policy to set catchment limits as part of the People, Water and Land Programme. DairyNZ used 41 dairy farms, to model possible mitigations to reduce nitrogen leaching and phosphorus losses through OVERSEER and FARMAX. These case study farms were selected broadly in proportion to the number of farms in each FMU. These farms are all unique with a wide variety of soil types, rainfall, farm systems, wintering practices, off-pasture structures and farm management ability reflected through operating profit.

The largest drivers of farm nutrient losses in OVERSEER are the environmental factors such as soil type, rainfall and farm contour. Given the level of variability and a need to understand the distribution of impacts, the mitigation curves for individual farms are provided rather than an average for each FMU. The nutrient losses reported in this project are for individual farms and they are not suitable for deriving average nutrient loads for FMUs. Weighted averages for particular zones will be used in **The Southland Economic Model for Fresh Water**.

OVERSEER has limitations including the use of long term average rainfall data, which does not capture one off storms or events in particular years. It also assumes good management practice for a number of components such as tile drainage is working effectively and that effluent and nitrogen is applied evenly over the application area. This may understate the amount of mitigation required on some farms. OVERSEER is also limited in estimating phosphorus losses as it does not take into consideration location of waterways, water run-off patterns and any critical source areas. From this perspective the phosphorus modelling in this study is limited and should be interpreted carefully.

The modelling has been conducted in the absence of any specific policies. This includes the proposed Water and Land Plan 2016 which was not developed when this work commenced. The modelling is based on an output regulation approach where reducing nitrogen leaching and phosphorus losses by 10%, 20%, 30% and 40% for each farm is targeted. The mitigations are largely based around reducing various inputs, but as it is a system approach one change in an input has an impact on other components within the farm. Some farms may choose to invest in larger capital items such as barns, sediment traps or wetlands to assist with mitigating nutrient losses. Some of these have been investigated, but many are very dependent on the individual farm's characteristics and some cannot be modelled in OVERSEER, so were not modelled for this study.

Mitigation curves for each farm were created to show the changes in operating profit per hectare resulting from the mitigations to achieve the target reductions for both nitrogen and phosphorus separately. Where farms have support blocks with sufficient data the milking platform and support block are amalgamated. Nutrient losses from the milking platform only can be shown separately for the base position. Overall, at an FMU level the addition of the support blocks has little impact on the nutrient loss results, but it will make quite a difference to individual farms depending on the size and how the support block is used.

The results for both base nutrient loss and mitigation impacts show no significant differences between the four FMUs. However, there is a wide variation between farm results across the region largely due to soil characteristics and the interaction of rainfall (including irrigation) and system type with these soils. There was no difference between the average nitrogen losses for farms with and without off pasture structures.

The results show that the average nitrogen leaching from the 41 Southland farms was 38 kg N/ha/year with 55% of farms leaching between 25 and 45 kg N/ha/year (total hectare). There is a wide variation in the impact on operating profit per farm at each mitigation level with the spread increasing the higher the reduction target. Of the 41 farms, 31 farms can achieve a 30% reduction in nitrogen leaching and 12 farms can achieve a 40% reduction. The majority of dairy farms cannot achieve a 40% reduction in nitrogen loss without significant changes in system or major capital expenditure e.g. infrastructure or wetlands.

The average phosphorus loss from the 41 Southland farms was 0.9 kg P/ha/year with 59% of farms recording losses between 0.5 and 1.1 kg P/ha/year. There is a wide variation in the impact on operating profit per farm at each mitigation level with the spread increasing the higher the reduction target. Only 19 of the farms can achieve a 15% reduction in phosphorus loss and only nine farms can achieve a 20% reduction.

A sensitivity analysis was conducted for various milk prices. As part of this sensitivity analysis interest and rent payments from each farm were also analysed. The results show that milk price will impact on the ability of farms to pay for mitigating nutrient losses. This will change for each year impacting farmer's decisions and therefore could also affect nutrient losses prior to mitigation. Farms need to return a positive operating profit after any required mitigation, in order to pay other financial obligations (including interest, rent and tax). Farms that cannot do this will no longer be viable businesses. It is important that cash flows are also considered when creating policy.

Based on this modelling, important factors are the variations in base nutrient losses for farms, the individual choice of farmers to run various systems, and for farmers to be able to choose the mitigations suitable for their own farm. The costs of mitigating nutrient losses are likely to impact on land prices, which were outside the scope of this study. These impacts will be considered along with land use change in **The Southland Economic Model for Fresh Water**.

4. Arable

Summary Points

Southland's arable sector is dynamic. Arable farmers respond quickly to market opportunities and their farm systems are able to change rapidly to capitalise on these opportunities.

Most Southland arable farmers have mixed systems. These systems have some or all of these options; cash crops such as grains, seeds and forage crops for the pastoral sectors, breeding stock; sheep, beef and deer, store stock for finishing and winter dairy grazing.

Environmental losses from arable farms are highly dependent on the system. Farms with a large proportion of cropping have lower nutrient losses than those with stock systems.

Arable farmers use gross margin analysis to compare the profitability of different farm system options. This provides a simple and quick way of deciding whether one crop or stock option is a better than another.

Complex arable systems are difficult to model in OVERSEER. At best they are time consuming because of the large number of blocks to be modeled and at worst crops and management practices are not represented in the model and substitutions must be made. When this happens, farmers have a low level of confidence with the nutrient report numbers.

Authors: Diana Mathers (Research Manager – Farm Systems), **Foundation for Arable Research**; and **Environment Southland** staff.

Arable farms in Southland tend to be family owned and operated businesses and are usually highly complex mixed enterprise systems. Arable farmers have highly flexible farm systems based around different seasonal crops to take advantage of changes in the market and compare the revenue from a range of crops and stock options when making business decisions about their enterprises. Arable farmers are familiar with gross margin analysis and use ProductionWise, an on-line crop management tool, to track crop production costs and analyse and compare crop gross margins.

The Foundation for Arable Research (FAR)[24] does not run an economic service for the sector and does not routinely collect financial information from its members.

Earnings before interest and tax (EBIT) was used for the purposes of this research as a financial measure to help with consistency between the sectors. For arable farming:

Gross margin is the income for the crop (yield (tonnes) x contract price ($)) - the production costs for the crop (crop inputs and management costs); and

EBIT is (inventory + income from crops) - (variable costs + fixed costs + wages of management).

[24] The Foundation for Arable Research (FAR) collect an Arable Commodity Levy from farmers on wheat, barley, oats, maize, pulses, herbage seeds, brassicas, borage, vegetable seeds and cereal silage. The levy is collected at the first point sale for all grain and seed, with the exception of maize which is collected on the seed purchased. FAR work closely with arable farmers in Southland and invest their levy in research and extension to improve farm performance and profitability.

Arable farmers do not use the farm management tool FARMAX and prefer not to use OVERSEER because these tools were designed primarily for pastoral farms.

OVERSEER was used to prepare nutrient budgets for the case study farms and for mitigation modelling. MPI and FAR decided to use a model farm, which is a different approach for the economic modelling than that used by the pastoral industries.

In general, the arable work was divided into two parts. First, four farms were surveyed across Southland and this information was used to model baseline nutrient losses and losses following nitrogen and phosphorus mitigations. Second, a model farm for Southland was created to explore the relationship between nitrogen inputs, nitrogen loss and crop yield. The four case studies are presented in the following section. The financial analysis for the model farm for Southland and modelling of nitrogen input mitigations for wheat and barley are described in the subsequent two sections.

Case Study Farms 1 to 4

Three arable case study farms were surveyed and this information was used to create base files in OVERSEER. Mitigations were modelled for the two farms that it was possible to apply mitigations to in OVERSEER. The third farm's nutrient losses were too low for mitigation modelling to be effective.

Following the completion of these three case studies, a fourth case study for a dairy support block was surveyed and this information was used to create base files in OVERSEER. Mitigations specific to fodder crops were modelled for this farm block.

Financial data was not collected for any of the case study farms because FAR does not collect financial information from its members.

Model Farm for Southland

A financial analysis was done for a model arable farm for Southland. The areas of crop on this model farm were based on the land area of different arable crops in the region using Statistics New Zealand's Agricultural Production Survey for 2012. Generic crop information was used from the FAR database for the variable costs to develop gross margins for the different crops.

The financial analysis was then used in the modelling of nitrogen input mitigations for the wheat and barley crops. These crops were chosen because the crop yield responses to nutrient supply, developed from recent FAR research, are readily available.

4.1. Case Study Farms

4.1.1. Farm Selection

The farm selection occurred in two phases. FAR first selected three arable farms in Southland to survey and model, and prepared case studies for each farm. Once this phase was completed, FAR developed a fourth case study specifically for a dairy support block.

In the first phase, the original intent was to survey one farm in each of the three FMUs where arable farming predominantly occurs in Southland (the Matāura, Ōreti and Aparima). Two of the case study farms are located in the Matāura FMU (one in the upper Matāura and one in lower Matāura) with the third farm in Aparima FMU. The three case study farms ranged in size from 206 hectares to 790 hectares (total hectares). The range in effective hectares across the 3 case study farms was 90 to 94% of the total farm area, and conversely the range in ineffective hectares was 6 to 10%.

These three case study farms were specifically chosen from the FAR database to represent a range of arable farm systems in the areas across Southland where short-rotation cropping ground has been identified. This sample size is relatively small for an industry with considerable variability in enterprise structure. As a result, care needs to be taken in applying the results more generally to other Southland arable farms. While the selection is small, it does include all the main arable crops and stock enterprises in Southland. However, it may not cover the full range of management practices arable farmers use in their farm systems. Arable enterprises were also captured within the drystock farm survey.

In addition to arable crops, intensive dairy grazing over winter is now a key component of many arable farms. Arable farms with dairy grazing were not targeted in the selection of the first three case study farms because separate work for dairy support farms was planned through **The Southland Economic Project**. Ultimately, however, this separate work did not occur because information on dairy support was available from both the dairy and drystock case study farms and Environment Southland's regional survey of winter forage crop in 2014. One of the three case study farms did include dairy grazing and subsequently a fourth arable case study farm with dairy grazing was added to fill this gap.

Farmers report that their biggest concern following winter dairy grazing is the long-term impact to soil structure, which in turn impacts on the yield of the following crops and imposes additional costs for soil remediation. To accommodate winter grazing in the rotation, many farmers will select the lighter, free-draining soils on their farms, avoiding soils that are vulnerable to pugging.

The dairy grazing block in this case-study is a small part of a large mixed arable enterprise, comprising mixed cropping and stock enterprises on owned and leased land. The environmental and economic performance of the block was modelled using OVERSEER and a gross margin analysis.

The general approach for the first three case study farms was to collect environmental and farm management data for OVERSEER modelling directly from the farmers through farm visits. This information covered a two year period of their rotations, starting in April 2012 and finishing in March 2014.

OVERSEER files (budgets) were developed using the case study farm records, and data entry followed the OVERSEER Best Practice Data Input Standards. Soil information for the farm was gained either from S-Map, or in the case of Farm 2, with reference to the Southland Topoclimate maps. Overall, the three farms covered a range of poor and well-drained soils. Climate information was generated from the OVERSEER climate station tool and the farm's GPS co-ordinates. Annual rainfall for the four case studies ranged from 773 mm to 1,122 mm and one case study had irrigation.

The number of management blocks across the three farms ranged from 20 to 35 blocks and reflects the complex nature of arable farming.

4.1.2. Farm Characteristics

Farm 1 - Arable

Farm System: The farm is a family owned and operated business with mixed cropping and sheep.

- The grain crops grown during the rotational period were wheat, barley, and oats.
- Forage crops grown for farm stock were turnips and/or swedes and annual ryegrass.
- Long term pasture comprised 33% (61 hectares) of the effective farm area.
- The sheep enterprise had 1,000 breeding ewes with a lambing rate of 135%. The majority of the lambs were sold by the end of January.
- Crop percentage changes year on year indicating a highly flexible system.
- The farm's baseline nitrogen loss was 39 kg N/ha/year.
- The farm' baseline phosphorus loss was 1.2 kg P/ha/year.

Farm blocks	1 property in 28 management blocks
Total area	206 hectares
Effective area	186 hectares (90% of total hectares)
Climate	Mean temperature 9.9 °C
	Mean rainfall 1081 mm/year
Soils	Poorly drained (Aparima deep silty loam, Makarewa undulating deep clay, and Otamamomo undulating deep)

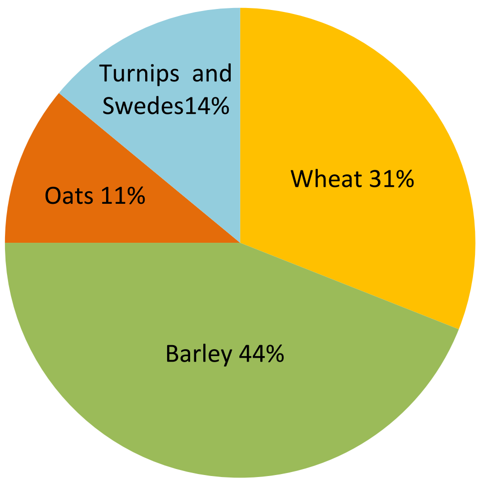

Figure C78: Crop composition for Farm 1

Farm 2 – Arable (with dairy grazing)

Farm System: The farm is a family owned and operated business with mixed cropping, deer, heifer grazing and dairy grazing over winter.

- The grain and seed crops grown in this rotational period were: wheat, barley, oats, ryegrass seed and peas.
- Fodder beet and kale forage crops were grown for the animal enterprises.
- 350 hinds, their replacements and progeny were grazed on the two land units with deer fencing.
- 1,880 dairy weaners and heifers were grazed on all 5 land units.
- Winter dairy grazing (500 cows) confined to one land unit, (17% of the farm area).
- In the OVERSEER modelling all five units were modelled as one farm. Paddocks with the same soil and crop rotation were blocked as one unit.
- The farm's baseline nitrogen loss, comprising the 5 properties, was 31 kg N/ha/year.
- The farm's baseline phosphorus loss was 0.2 kg P/ha/year.
- The soils on the Waimea block are shallow stony silt loams. It was the only block on the farm used for winter dairy grazing and was deliberately selected because of the reduced risk of soil damage during wet weather.

Blocks	5 separate properties in 35 management blocks
Total area	790 hectares
Effective area	740 hectares (94% of total hectares)
Climate	Mean temperature 9.8 °C
	Mean rainfall 773 mm/year
Soil	Well-drained (Waikoikoi, Ardlussa and Matāura silt loams)

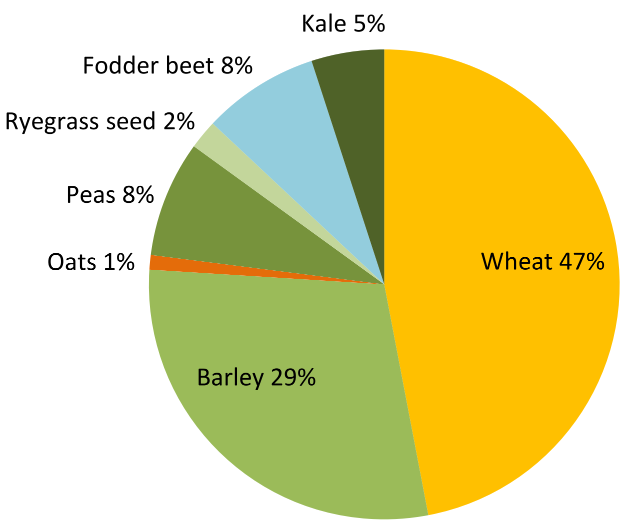

Figure C79: Crop composition for Farm 2

Farm 3 - Arable

Farm System: The farm is a family owned and operated business with mixed cropping, and no stock.

- The crops grown during this rotational period were wheat, barley, and oil seed rape. Oats and peas were also grown as part of the rotation.
- Farm 3 had no stock enterprises and relatively low nitrogen and phosphorus losses.
- The farm's baseline nitrogen loss was 7 kg N/ha/year.
- The farm's baseline phosphorus loss was 0.1 kg P/ha/year.
- This farm is the simplest of the arable farm systems in Southland, not having the rotation through the cropping and pastoral enterprises of other arable farms. The importance of this case study farm is its results indicate a possible lower benchmark for arable farm systems in the region.
- No nitrogen and phosphorus mitigation modelling was done for this case study farm because its fertiliser use is considered to already be at good management practice and the crop rotation does not have any pasture phases to adjust.

Blocks	2 separate properties in 20 management blocks
Total area	242 hectares
Effective area	222 hectares (92% of total hectares)
Climate	Mean temperature: 9.1 °C
	Mean rainfall: 840 mm/year
Soils	Well-drained (Crook, Crookston silt loam, Kaweku silt loam)

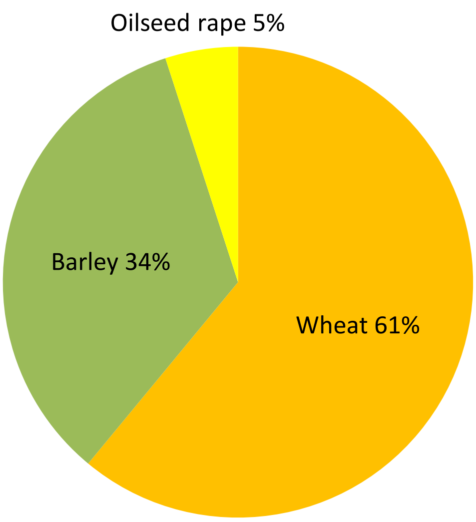

Figure C80: Crop composition for Farm 3

Farm 4 – Dairy Support Block

Farm System: A modelled case study dairy grazing block, which is a small part of a large mixed arable enterprise, comprising mixed cropping and stock enterprises on owned and leased land.

- 44 hectares of the property were sown in swedes and kale over a rotational period of two years.
- The remaining area has been a 17 hectare lucerne cut-and-carry block for the past 2 years.
- Farm 4 had dairy cows grazing over the winter period (from start of June to mid-August) with relatively high nitrogen and phosphorus losses.
- The dairy grazing block's baseline nitrogen loss was 36 kg N/ha/year.
- The dairy grazing block's baseline phosphorus loss was 1.3 kg P/ha/year.

Blocks	Single dairy grazing runoff in 6 paddocks
Total area	64 hectares
Effective area	61 hectares (95% of total hectares)
Climate	Mean temperature: 9.8°C Mean rainfall: 1,122mm/year
Soils	2 soil types; 42% well-drained (Riversdale silt loam), and 58% poorly drained (Eureka silty loam)

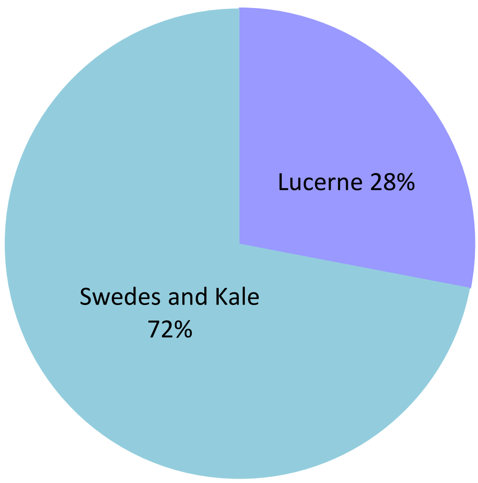

Figure C81: Crop composition of Farm 4 – dairy support block

4.1.3. Farms 1, 2 and 3 – Baseline and Mitigations

This section outlines the possible mitigations for reducing nutrient losses (nitrogen and phosphorus) in OVERSEER and identifies the mitigations used for Farms 1 and 2. Farm 3's baseline nutrient losses were low (7 kg N/ha/year and 0.1 kg P/ha/year) so no mitigation modelling was done for this farm. The next section presents the results of the baseline modelling for Case Study Farms 1 to 3 and the mitigation modelling for Case Study Farms 1 and 2.

The mitigations selected for modelling on Farms 1 and 2 were those that had a reasonable likelihood of being implemented without changing the essential characteristics of the case study farms. For example, the mitigation tested to reduce nutrient losses following winter dairy grazing was to model the impact of hosting a lighter stock class.

Mitigations for nitrogen losses for these case study farms were selected from the following list:

1. Reduced nitrogen fertiliser rates and improved timing. Nitrogen rate changes can be modelled in OVERSEER. However, nitrogen application timings can only be modelled monthly;
2. Planting crops in the rotation to reduce fallow periods. Fallow periods can be modelled in OVERSEER;
3. Understanding the nitrogen supply from mineralisation processes following the cultivation of long-term pasture for cropping. Length of time in pasture can be modelled in OVERSEER as crop history; and
4. Understanding the nitrogen supply to the crop following grazing. The nitrogen load following grazing is dependent on stocking rates and grazing time, with both being able to be modelled in OVERSEER.

Mitigations for phosphorus losses able to be modelled in OVERSEER were:

1. Fertiliser product and timing; and
2. The addition of grass filter strips on grazed paddocks with rolling contours.

In reality, farmers manage in real-time, responding to the weather and the market for their day to day decisions. They will sometimes be unable to change or improve management practices because of weather constraints, or the absence of preferred crop and stock options. It may not be feasible to change the length of the farm rotation to reduce long pasture phases, or select planting and harvesting dates and manage grazing systems differently.

The majority of farmers are well aware of industry good management practices, but at times they make deliberate decisions to follow an alternative approach. A good example of this is the need to revert back to ploughing and full cultivation practices to control persistent grass weeds which establish after periods of minimum tillage.

Nitrogen Mitigations – Farms 1 and 2

As already discussed, nitrogen mitigations were only modelled for Farms 1 and 2 (not Farm 3). The OVERSEER reports and graphs for the individual blocks on Farms 1 and 2 indicated that nitrogen was being lost at specific points in the cropping and pasture rotations. These points were associated with key management practices for arable farms: fertiliser management (amount and timing) and rotation management.

Based on this information, there were two realistic mitigations for reducing nitrogen losses in cropping rotations that could be modelled in OVERSEER:

Fertiliser management – adjusting fertiliser use and timing of fertiliser applications; and

Rotation management – reducing the length of pasture and fallow phases in the crop rotation.

There are likely to be other mitigations that are relevant for arable farms in Southland but they cannot be modelled in OVERSEER, such as the variable rate management of nitrogen fertilisers.

Fertiliser Management (amount and timing)

Fertiliser management is a critical part of an arable farm and fertiliser applications are timed to meet the crop demand. Nitrogen fertiliser applications are avoided between May and July when crop growth is slow and there is an increased risk of rain and drainage events. Soil testing to measure residual nitrogen levels is particularly important following crops that did not achieve their planned yields and after long–term pasture has been cultivated.

The mitigation for reducing high nutrient losses associated with fertiliser use is to develop a pre-season "mass balance" nutrient budget for each crop. This type of budget is one of FAR's good management practices and reflects the direct relationship between supply of nitrogen and crop yield. A nitrogen budget calculates a crop's demand for fertiliser based on the planned crop yield and the supply of nitrogen in the soil (which is determined by soil testing).

> *The mass balance equation is:*
> *Applied fertiliser rate = crop demand for fertiliser – soil supply of nitrogen.*

Rotation Management (length of time)

Rotation management includes reducing the number of years land is in pasture before cultivation and the establishment of the crop. In general, the longer this pasture phase, the bigger the contribution to soil nitrogen from mineralisation processes when the land is cultivated.

Rotation management also includes reducing fallow periods between crop rotations when the cultivated land is more prone to erosion and phosphorus losses. However, it is not always possible to reduce fallow periods. During late autumn and winter in Southland it is common for ground conditions to be too wet for cultivation and crop establishment, and there are unplanned fallow periods occur where water runs off from cultivated paddocks and grazed areas. In situations where soils are saturated farmers will often make a deliberate decision to delay cultivation because of the increased costs involved and the high risk of soil compaction and long term damage to the soil structure.

Phosphorus Mitigations - Farm 1

Phosphorus losses associated with fertiliser use are related to the solubility of the fertiliser and the timing of the application. Phosphorus mitigations were only modelled for Farm 1. The OVERSEER predicted phosphorus losses for Farms 2 and 3 were low and phosphorus mitigations were not modelled.

The key mitigations for reducing phosphorus losses from cropping ground relate to fertiliser use and sediment control.

Olsen P is a measure of the readily available phosphorus in the soil. It is used to determine how much phosphorus fertiliser should be added to maintain the soil at an optimal range for the crops.

Olsen P levels for Farm 1 were not collected, so it was not possible to assess whether phosphorus fertilisation could be reduced. However, for the purpose of examining possible mitigations reduced applications were modelled. In situations where phosphorus losses are known to be high and phosphorus fertilisers are required, a practical mitigation is to use less soluble forms of phosphorus fertilisers such as RPR (reactive phosphate rock).

Phosphorus losses from the arable farms are associated with sediments being lost from bare, cultivated land and during or following grazing. The key mitigation for reducing both sediment and phosphorus losses in cropping rotations that can be modelled in OVERSEER is to reduce erosion and sediment movement in run-off water associated with both cropping and grazing.

4.1.4. Farms 1, 2 and 3 – Results

Baseline Results (Farms 1, 2 and 3)

In terms of nutrients added, Farm 2 had the lowest fertiliser use for nitrogen and phosphorus, Farm 3 had the highest for nitrogen, and Farm 1 had the highest for phosphorus. Farm 3 had extremely low rain/clover nitrogen fixation compared to the other two farms because it has no pastoral enterprise. As for nutrients removed, Farm 2 has the lowest amount of nitrogen and phosphorus removed as products and Farms 1 and 3 are roughly similar for both nitrogen and phosphorus. However, Farm 3 had by far the lowest amount of nitrogen and phosphorus losses to water. Across the three case study farms, nitrogen losses ranged from 7 to 39 kg/ha/year and the phosphorus losses were from 0.1 to 1.2 kg/ha/year.

Table C23 gives the baseline nutrient results for the first three case study farms: the x axis reports each farm's nitrogen losses and the y axis reports phosphorus losses. All results are on a per hectare basis.

Table C23: OVERSEER nutrient budget for farms 1, 2 and 3

Nutrients (kg/ha/year)	Farm 1		Farm 2		Farm 3	
	N	P	N	P	N	P
Fertiliser, lime and other	169	43	87	27	206	34
Rain/clover nitrogen fixation	44	0	45	0	3	0
As products	162	34	113	24	171	36
Supplement & crop residues	43	4	43	4	102	12
To water	39	1.2	31	0.2	7	0.1

Figure C82 below shows the current performance (or baseline) results for nutrients losses to water for all three farms. It does not show the relationship between losses of either of these nutrients and profitability (which is unknown for the arable farms).

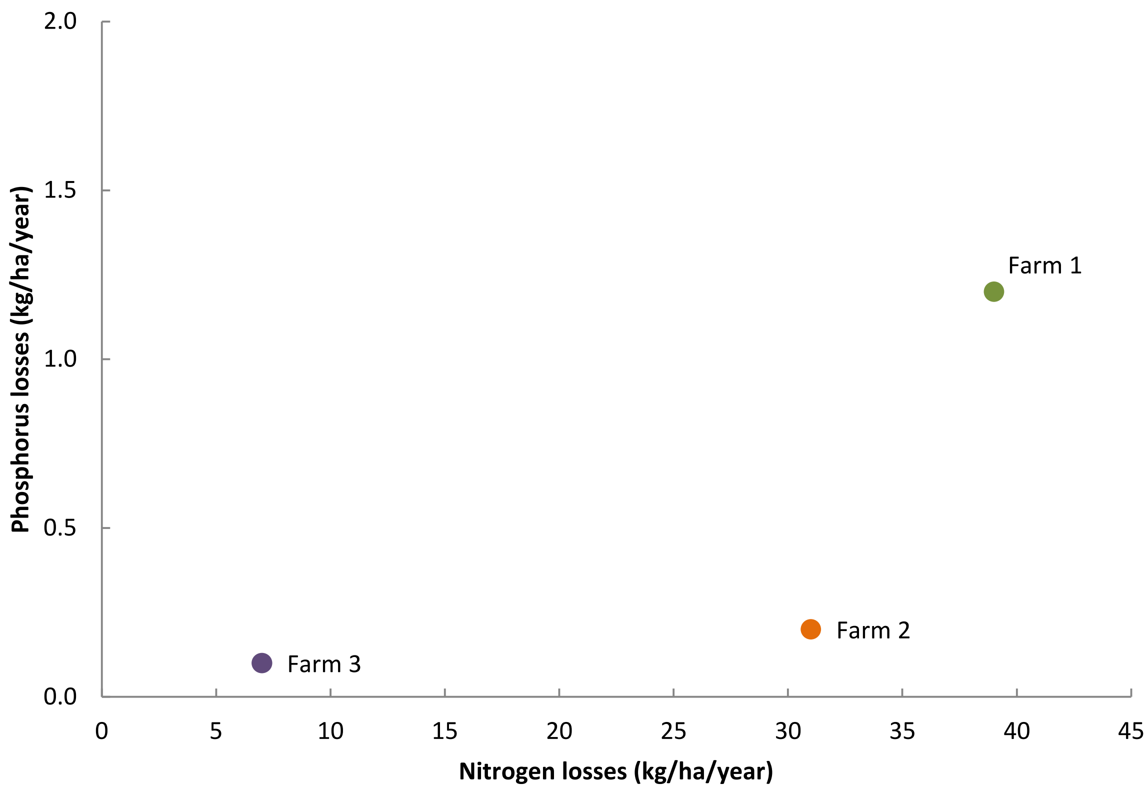

Figure C82: Baseline nutrient losses for Farms 1, 2 and 3

Nitrogen Mitigation Results (Farms 1 and 2)

Specific mitigations applied in the modelling exercise for Farms 1 and 2 were:

Fertiliser management: Reduce the amount of nitrogen applied to some grain crops in line with the nitrogen strategy information for grains developed by FAR[25]; and alter the timing of the applied fertiliser to meet the crop demand through its fastest growth period.

Rotation management: Reduce the pasture phase in the rotation from 6 years to 4 years; and use cover crops in fallow periods. Note both farmers agreed that this was not a practical option.

Most arable farmers make fertiliser decisions on the long term averages for their crops. It is essential for the sustainability of their businesses that they understand the productive capability of their soils and their crop yield potentials and nutrient applications are optimised to achieve the best yields possible.

In the modelling exercise, the amount of applied nitrogen was only reduced if it was in excess of the planned crop yield. The nutrient requirement for the crop at its planned yield was determined from a crop nutrient-response curve so yield was not constrained by a nutrient shortage. Applying these mitigations reduced nitrogen losses on both farms and came at no financial impact to the farmer.

Modelling of an arable farm where fertiliser is reduced below that necessary to grow the crop is shown in Section 4.3. Arable farmers do not usually talk about maintenance levels of fertiliser ("maintenance fertiliser" is a pastoral term), however they will not let soil mineral nitrogen levels drop below 150 kg N/ha.

Table C24 gives the key results from the nitrogen mitigation modelling for Farms 1 and 2. These results are also shown in comparison to the baseline results in Figure C83.

Farm 1

For Farm 1, the modelled mitigations reduced nitrogen loss by 49%, from 39 to 20 kg N/ha/year. The farm was using too much nitrogen fertiliser, so this was reduced to a good management level, which does not impact of growth rates or yields. A reduction in the length of the pasture phase was also modelled, especially as the nitrogen applications following the initial cultivation were reduced to allow for the increased soil nitrogen supply through mineralisation processes. Better fertiliser management, both the rate and the timing were the most effective mitigations for this farm.

Farm 2

For Farm 2, the modelled mitigations reduced nitrogen loss by 13%, from 31 to 27 kg N/ha/year. Nitrogen was generally not over-applied on this farm and this farm had dairy grazing over the winter months. The most effective mitigations were to reduce the nitrogen applications following grazing and to reduce the fallow periods following grazing with a forage oat crop which was cut and baled. These mitigations were effective at reducing part of the nitrogen loss associated with leaching but reducing the fallow period was not considered to be a practical option by the farmers because of the risk for a delayed planting for the next cash crop in the rotation.

[25] https://www.far.org.nz/assets/files/blog/files/6e17b639-db58-4541-8594-113be7ac6a5b.pdf

Table C24: OVERSEER Results for Farms 1 and 2 following nitrogen mitigations

Nutrients (kg/ha/year)	Farm 1		Farm 2	
Nutrients added:	N (Base #)	P (Base #)	N (Base #)	P (Base #)
Fertiliser, lime and other	123 (169)	27 (43)	84 (87)	26 (27)
Rain/clover nitrogen fixation	44 (44)	0 (0)	62 (45)	0 (0)
Nutrients removed:	N (Base #)	P (Base #)	N (Base #)	P (Base #)
As products	166 (162)	35 (34)	110 (113)	23 (24)
Supplement & crop residues	45 (43)	4 (4)	36 (43)	6 (4)
To atmosphere	45 (56)	0 (0)	35 (29)	0 (0)
To water	20 (39)	1.2 (1.2)	27 (31)	0.2 (0.2)

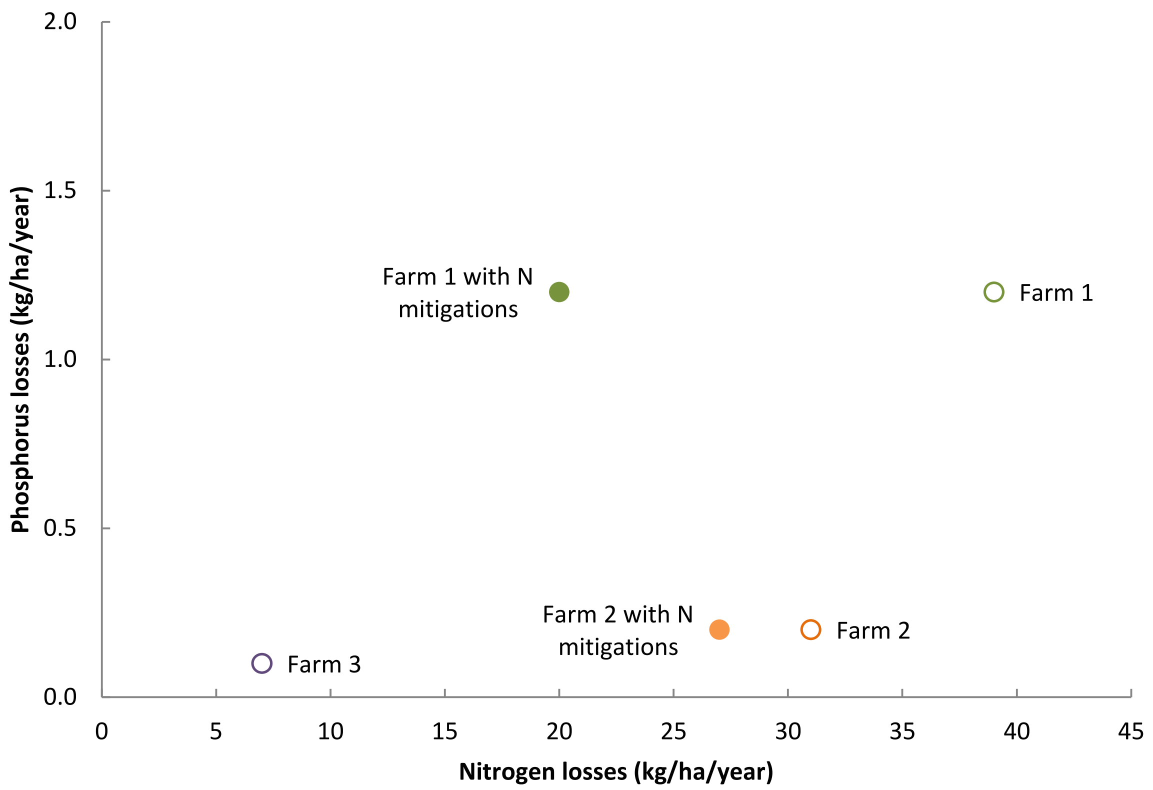

Figure C83: Effect on nitrogen mitigations on nutrient losses for Farms 1 and 2

Phosphorus Mitigation Results (Farm 1)

The base OVERSEER report indicated phosphorus losses on Farm 1 were 1.2 kg P/ha/year.

The specific mitigations modelled for Farm 1 were:

1. Reduce phosphorus applications by at least half and sometimes completely. This may not be a practical option where the farmer is maintaining soil phosphorus levels within the optimal levels for the crops;
2. Model a grass filter strip on the sloping grazed blocks; and
3. Reduce fallow periods after winter grazing on forage blocks. This may not be a practical option as wet conditions may prevent ground work being completed in a timely way.

The results shown for the phosphorus mitigation modelling on Farm 1 in Figure C84 reduced phosphorus loss by 25%, from 1.2 kg kg/ha/year to 0.9 kg/ha/year.

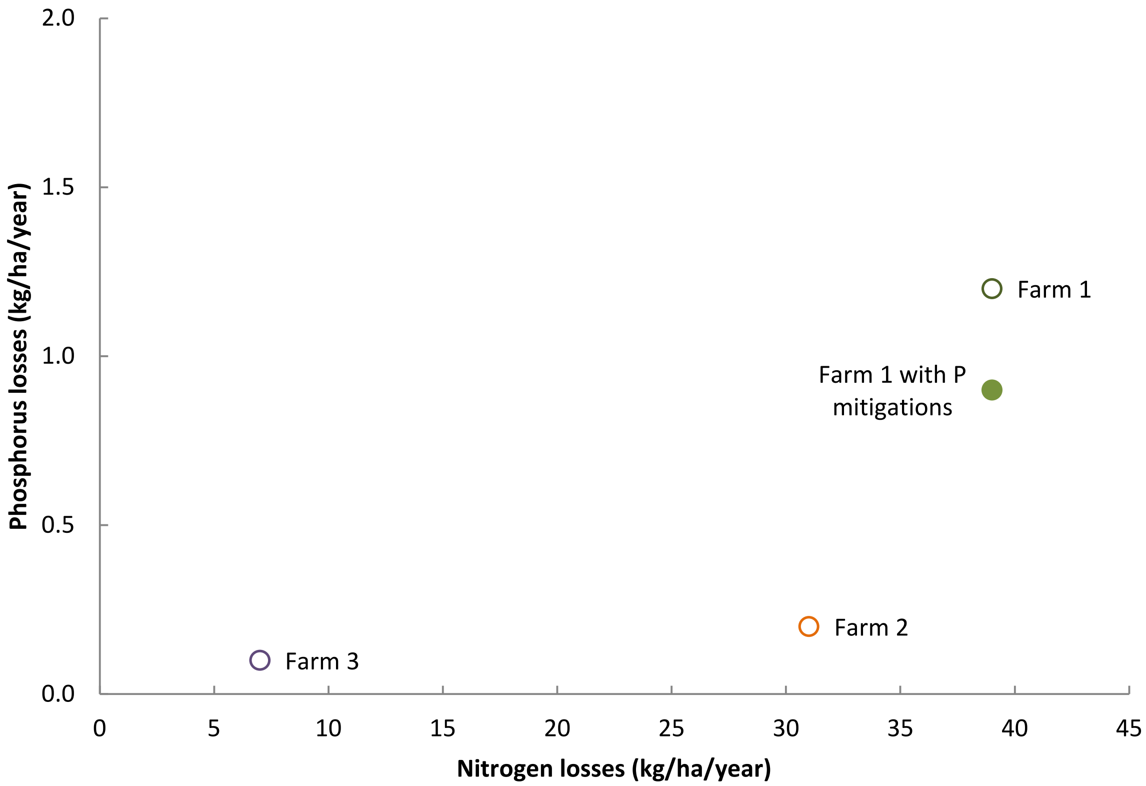

Figure C84: Effect of phosphorus mitigation on nutrient losses for Farm 1

Farmers Feedback on the Mitigations Modelled (Farms 1 and 2)

The farmers involved were given the opportunity to comment on the mitigations modelled for the three case study farms. Their feedback covered four main points:

1. The farmers agreed that the mitigations were consistent with industry good management practice.
2. They raised concerns about the ability of OVERSEER to model arable farms. In many respects these are justified as OVERSEER does not capture some of the subtleties of their management practices. Examples include fertiliser timing, stock management on cropping paddocks with mixed forage crops and feed allocation on cropping blocks. A distrust in OVERSEER works against their acceptance of mitigations.
3. They noted the difference between a desk top exercise and "real" farming. Farm decisions are a response to external factors, such as weather and markets. They are deliberate decisions made in real time, whereas desk top exercises could model mitigations that are not practical.
4. The farmers expressed concern that regulators have little understanding of their businesses and their management constraints.

4.1.5. Farm 4 – Baseline and Mitigations

Environmental risks associated with winter dairy grazing arise from the management of the crops, both the forage crop for grazing and the crop following the grazing event, and management of the stock during their stay. The economic performance of the system relates strongly to the number of cows grazed, which in turn depends on the dry matter (DM) production of the forage crop

The most obvious mitigation for the environmental effects of winter dairy grazing on cropping ground is to not do it at all. However, the dairy industry see wintering-off of dairy cows as a mitigation for reducing losses on dairy farms and arable farmers are keen to host the cows because it is a profitable option for their businesses. Reducing stock numbers is an obvious mitigation for nutrient losses and soil damage, but income relates to the number of cows hosted for the season and the stocking rate is determined by the DM yield of the fodder crop. The aim of is for the best use of feed.

Scenario 1 (Baseline): the current system where 743 dairy cows are grazed on 44 hectares of kale with 17 hectares of cut and carry lucerne.

Two mitigation options (no dairy grazing and dairy grazing restricted to 15% of the block area) were considered that allowed for four mitigation scenarios (**Scenarios 2-5**).

Scenario 2: no dairy grazing in the rotation. Dairy grazing was replaced with winter wheat and spring barley and cut and carry forage and fodder crops (lucerne, annual ryegrass and fodder beet).

Scenarios 3-5: dairy grazing restricted to nine hectares (15%) of the block area and all of the rotations included winter wheat and cut and carry crops (lucerne, fodder beet, and annual ryegrass). These scenarios were developed because restricting the area of dairy grazing has been considered as a policy option over recent years.

> **Scenario 3**: dairy grazing on fodder beet; 380 cows on the heavy soil type;
>
> **Scenario 4**: dairy grazing on fodder beet; 380 cows on the light soil type; and
>
> **Scenario 5**: dairy grazing on kale; 153 cows on the light soil type.

Scenario 6: dairy grazing on fodder beet; 1,858 cows on the whole block. This final scenario was run as a comparison to the current system of dairy grazing on kale (Scenario 1).

OVERSEER modelling and gross margin analysis was completed for each of the new rotations. The farmer's gross margins for the crops were used but fixed costs were not considered. The block income was calculated for a single year of the rotation and includes the income and costs associated with the crops and the dairy grazing.

4.1.6. Farm 4 – Results

Table C25 summarises the dairy grazing scenarios and the results for OVERSEER nutrient losses and block income (gross margin). On paper, the current system of wintering on kale (Scenario 1) was less profitable than a system of grain crops, cut and carry forages and fodder crops and no winter grazing (Scenario 2). The removal of dairy grazing from Scenario 2 reduced the nitrogen loss to water from 36 to 14 kg N/ha/year. Figure C85 and Figure C86 show the results from the six modelling scenarios.

In practice, however, the options selected for modelling the no dairy grazing scenario may not be achievable or are risky to undertake. Lifting, moving, storing and feeding out a crop of fodder beet is a hassle and it is easier to graze the crop in situ. An additional challenge for a rotation with cut and carry fodder beet crops, is the establishment of the next crop in the rotation. Disruption by poor weather is always a risk, autumn harvest and replanting can be delayed and there may be extended fallow periods before the next crop is sown. Farmers assess risks to their bottom lines and are likely to choose the least risky option for their profit, irrespective of the environmental risks. Dairy grazing is a simpler option.

Scenarios 3-5 were developed to test the effects of a reduction in the area for winter dairy grazing. The option of constraining the area for dairy grazing was seen as a possible mitigation for dairy grazing on arable soils. To test the idea, the 44 hectare block was set up with a 9 hectare block for dairy grazing on fodder beet, either on the heavier Eureka soils or the lighter Riversdale soils. The original long-term lucerne blocks remained and the balance of the land was planted in cut and carry forage and fodder crops and winter wheat and spring barley, (Scenarios 3 and 4). In these scenarios, the profitability increased and there was no difference in income between the Eureka and Riversdale soils, but the lighter Riversdale soils had higher nitrogen losses. Restricting the cow number on the lighter soils by grazing on kale (Scenario 5) reduced nitrogen losses to water but reduced the profitability.

In this case study, Scenario 6, dairy wintering at a high stocking rate, on fodder-beet, supplemented with additional feed for nutritional balance, was the most profitable scenario and had the highest environmental risk. The nutrient loss results are per total hectare and the block income is per effective hectare.

Table C25: Dairy grazing scenarios

Scenario	Description	Stocking Rate	Block income	N loss (kg N/ha/year)	P Loss (kg P/ha/year)
1	Baseline: Lucerne and dairy grazing on 44 hectares of kale (current system)	17	$118,251	36	1.3
2	No dairy grazing: Lucerne, cut & carry fodder beet, winter wheat, spring barley, and annual ryegrass	0	$153,867	14	1.1
3	Lucerne, dairy grazing on 9 hectares of fodder beet (heavy soils) and cut & carry fodder beet, winter wheat and annual ryegrass	42	$183,725	21	1.2
4	Lucerne, dairy grazing on 9 hectares of fodder beet (light soils) and cut & carry fodder beet, winter wheat and annual ryegrass	42	$183,725	26	1.2
5	Lucerne, dairy grazing on 9 hectares of kale (light soils) and cut & carry fodder beet, winter wheat and annual ryegrass	37	$140,194	14	1.1
6	Lucerne and dairy grazing on fodder beet	37	$311,263	54	1.4

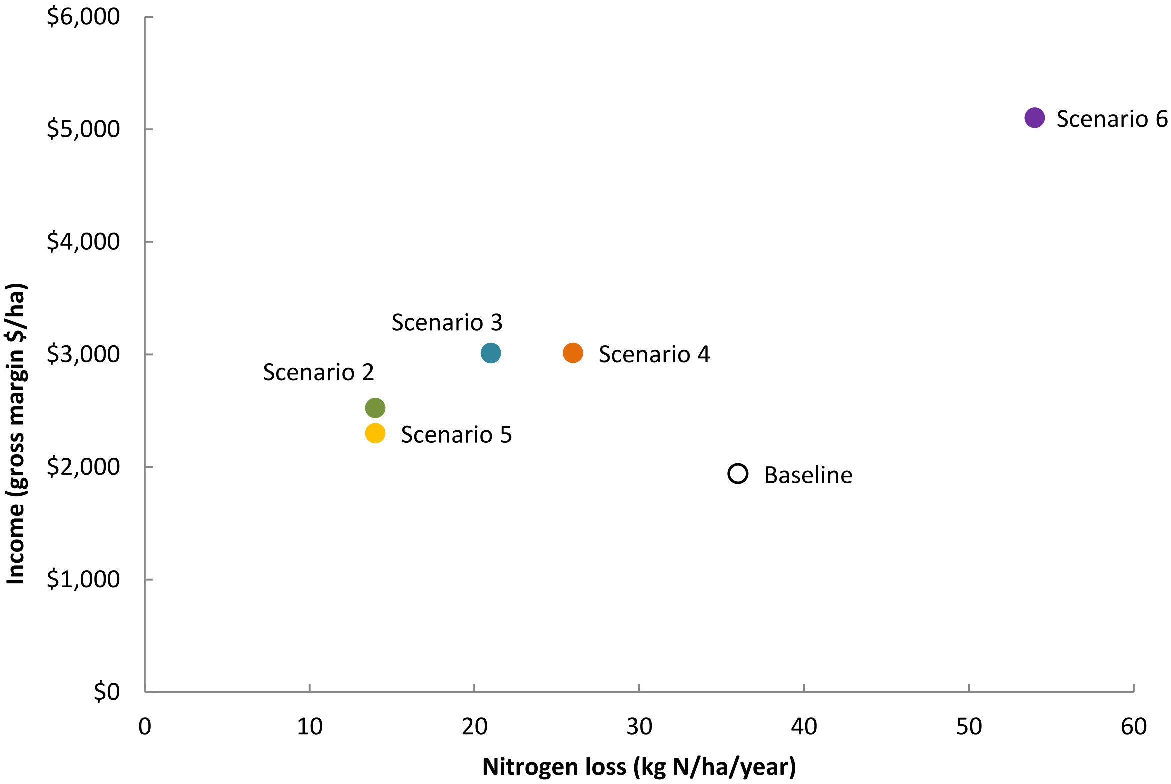

Figure C85: Results for nitrogen loss and income from 6 mitigation scenarios for Farm 4

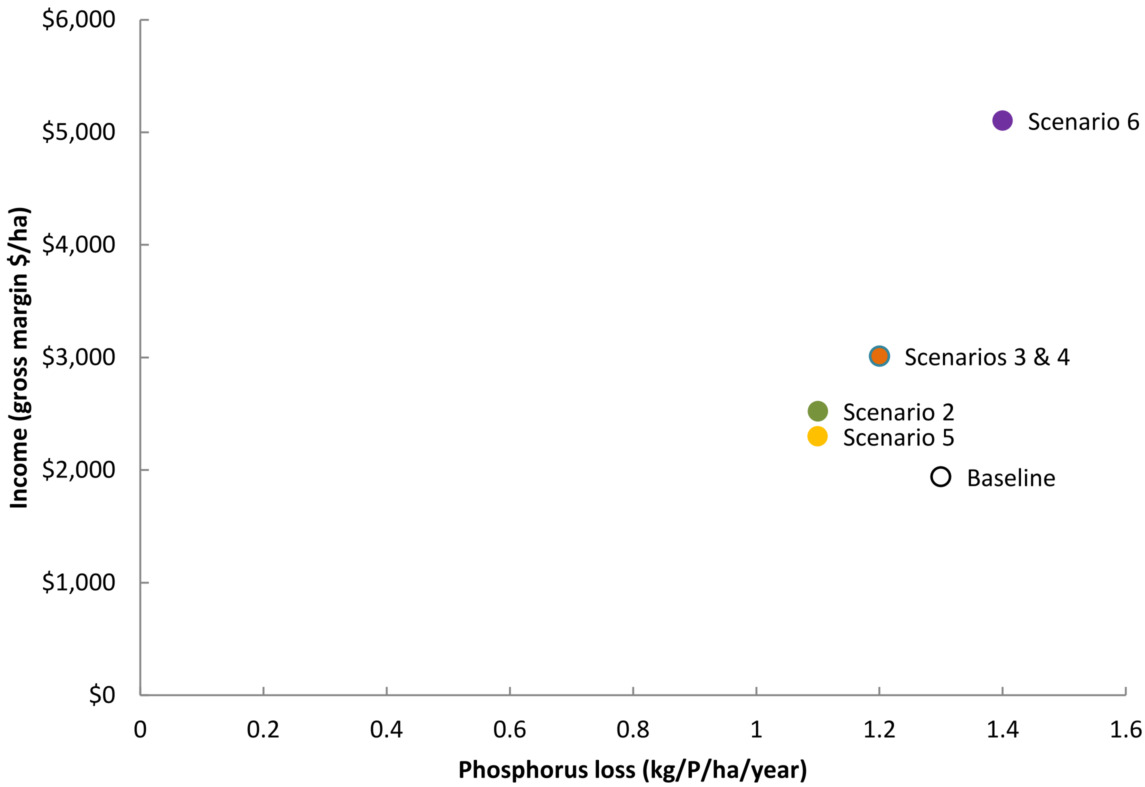

Figure C86: Results for phosphorus loss and income from 6 mitigation scenarios for Farm 4

__Farm 4 – Farmer Feedback and Discussion__

Fodder beet crops offer the opportunity of high stocking rates because of their high DM production but grazing them in-situ has a high environmental risk. The option of harvesting the beet for feeding out on a feed-pad or to housed cows is a possibility which delivers a number of benefits to the rotation. Lifting and removal of the crop in autumn allows for an additional crop to be planted in the rotation. The cost of soil damage from the grazing is not incurred and nitrogen losses are reduced. However, the cost of harvest and transport is high and if conditions are unfavourable during harvest there is a risk of soil damage from the harvesting machinery.

The farmer in this case study has considered a cut and carry fodder beet operation but rejected the idea on the grounds that he "can't make it pay" because of the transportation costs to move the beet off the farm. He has also considered building feed-pads for his wintering operation. These, along with an effluent management system for the feed-pad, were considered not to be feasible for the existing farm business. "If we were going this far, we might as well go all the way and become dairy farmers". A successful cut and carry fodder beet system is more practical on the dairy farm where transport is minimised and the crop is stored close to the feed out area.

This case study and case studies 1-3 show that arable systems have a range of environmental effects, as indicated by nutrient losses 'to water'. Apart from managing fertilisers, the most likely way nutrient losses from the farm will be reduced is by the selection of crop and stock options in the rotation, which only works well when farming is 'humming'. Then the choice of profitable options for the rotation is wider, especially if the sector is supported by local infrastructure for processing grain and seed crops.

4.2. Model Farm – Financial Analysis

This section presents a financial analysis for a model arable farm for Southland. The following section uses this financial analysis to model restricting nitrogen fertiliser use as a mitigation for barley and wheat. These crops were selected out of the range grown in Southland because there is reliable information on the yield response to the supply of nutrients.

Most arable farms are an integrated mix of cropping and stock enterprises. Considerable effort has been invested in modelling mixed enterprises within the sheep, beef and deer case study farms for Southland (**Part C** – Section 2) and this research also captured forage cropping and arable crops on some of those farms.

For efficiency, a model arable farm for Southland was developed for the financial analysis that focused on the cropping enterprise within an arable farm and was designed to capture all of the main crops in Southland. In reality, an arable farm will grow only some of these crops within any one year and its production system has a high degree of flexibility. Information relevant to the characteristics of Southland arable farms was drawn from Agricultural Production Statistics for Southland (Statistics New Zealand, 2013).

The financial analysis for the Southland model arable farm was based on a gross margin analysis of the component crops in cropping enterprise. No analysis was done for the stock enterprises of the model farm because it was covered within the sheep, beef and deer case study farms.

The following assumptions were used to develop the Southland model arable farm for the financial analysis:

1. The proportion of different crops can be based on the data for 2012 Southland in Statistics New Zealand's Agricultural Production Survey (Statistics New Zealand, 2016 updated);
2. The crops are grown in rotation with pasture and in any one year there is only one crop per paddock. Once the crop is harvested, grass or forage crops for the stock are re-sown. This assumption is consistent with mixed enterprises where harvestable crops are rotated with crops grown for grazing in situ or pasture;
3. Cereal silage is harvested and sold;
4. Forage brassica is grazed by farm stock, but not used for winter dairy grazing;
5. There will be grain inventory stored on the farm waiting for sale but each year it is all sold and silos are emptied to receive newly harvested grain (i.e. inventory was zero); and
6. The stock enterprises should be equivalent to analyses completed by B+LNZ for Southland sheep, beef and deer case study farms.

From the Agricultural Production Survey statistics, the Southland model arable farm was based on an effective area of 200 hectares, where 100 hectares (or 50% of the farm) of which was pasture for the stock enterprises (sheep/beef/deer); and 100 hectares (or 50% of the farm) was for the cropping enterprise.

For the model farm's 100 hectare cropping enterprise, the areas in each crop were sized proportionally to the percentage of cropping areas on arable farms in Southland in 2012 (Figure C87). For example, 26% of the cropping area was in feed wheat so 26 hectares of feed wheat was included in the model farm.

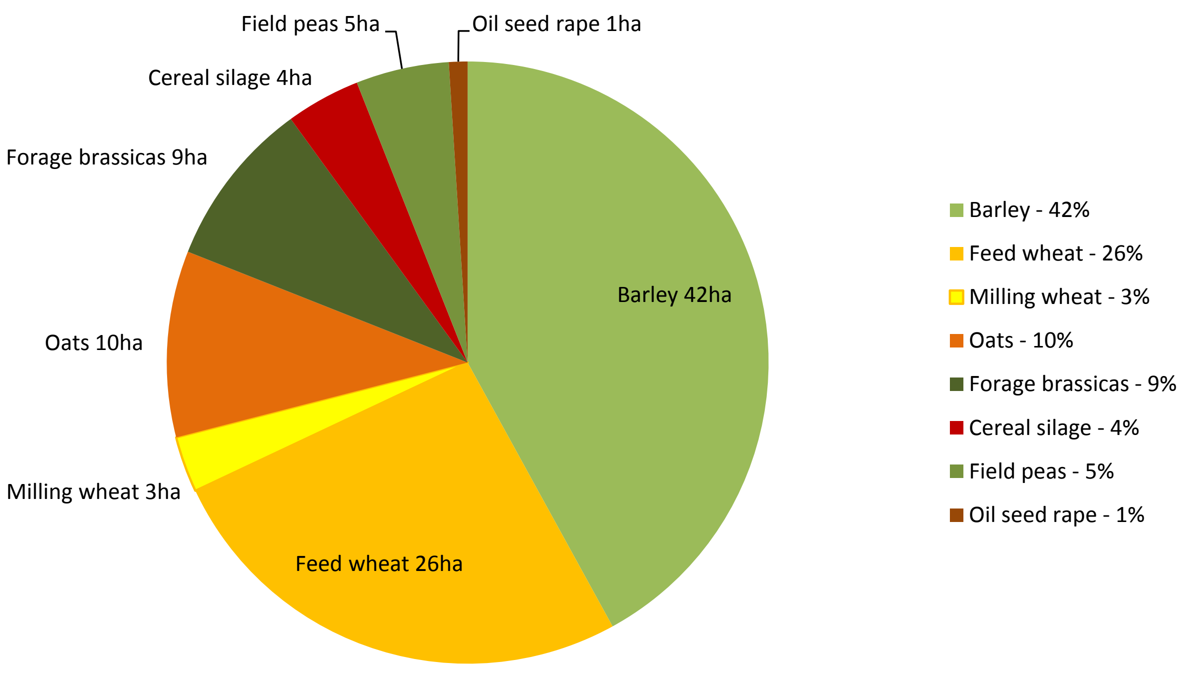

Figure C87: Crop proportions and areas in model arable farm for Southland, 2012

4.2.1. Methodology and Results

Arable farmers focus on gross margins in their decision-making because it is better suited to the seasonality of their farming systems than other financial measures, such as EBIT or EBITR, which is used in pastoral farming where the production systems more on an annual basis. However, EBIT was also calculated to give a common financial measure across all of the agricultural industries. The financial analysis for the Southland model arable farm was carried out in two steps:

Step 1: Gross margins were calculated (on a per hectare basis) for each of the crops in the cropping enterprise. These were based on the variable costs of growing each crop. Variable costs are all of the costs associated with the growing and harvesting of an arable crop. For example, cultivation costs, fertiliser costs, and costs related to spraying herbicides, transport.

Step 2: The gross margins were scaled up for the 100 hectares generic farm and used, together with other financial information (e.g. fixed costs and wages of management), to calculate EBIT for the cropping enterprise. EBIT = (inventory + income from crops) - (variable costs + fixed costs + wages of management).

Generic crop information from the FAR database was used for the variable costs. Contract prices for the crops were 2015 contract prices and yields are average yields for Southland in 2015. Prices and yields for the gross margin analysis are indicated in Table C26. Table C27 gives a summary of the gross margin analysis of income and variable costs for the farm. Table C28 summarises the EBIT analysis of all farm costs. Information on wheat and barley from this financial analysis is used in mitigation modelling in the next section.

In the gross margin calculation, it was assumed: the farm work was done by the farmer using his own machinery; there was no casual labour; there was no irrigation; the gross margin for each crop captures the costs associated with running farm vehicles (fuel, repairs and maintenance, depreciation) for the production of that crop[26]; fixed costs were estimates based on figures reported for Canterbury arable cropping (Ministry of Agriculture and Forestry, 2011) because similar figures for Southland were not available; personal drawings was the value used from the same report: Wages of Management (WOM) = $75,000; and the expenditure information used from this report was inflated by an annual increase of 1.5% to bring it in line with the current year (2015).

Table C26: Prices and yields for the gross margin analysis

Crop	Yield tonnes/ha	Contract price $/T
Barley	8	$360
Feed wheat	12	$350
Milling wheat	11	$425
Oats	6	$420
Cereal silage	16 (dry matter)	$300
Forage Brassicas	12 (dry matter)	$300
Field peas	3	$800
Oil seed rape	4.5	$700

[26] There may be additional vehicle costs associated with the farm enterprise not captured in the gross margin analysis.

Table C27: Gross margin income and variable costs

Gross Margin Income

Crop	**Cereal silage**	**Forage brassica (kale)**	**Feed Wheat**	**Milling Wheat**	**Barley**	**Oats**	**Field Peas**	**Oil Seed Rape**
Hectares	4	9	26	3	42	10	5	1
Income/hectare	$4,800	$3,600	$5,025	$5,335	$3,111	$2,970	$2,725	$3,150
Total Income	$19,200	$32,400	$130,650	$16,005	$130,662	$29,700	$13,625	$3,150

Variable Costs from Gross Margins for the Farm

Crop	**Cereal silage**	**Forage brassica (kale)**	**Feed Wheat**	**Milling Wheat**	**Barley**	**Oats**	**Field Peas**	**Oil Seed Rape**
Seed	$661	$911	$2,538	$293	$6,195	$840	$2,813	$30
Ground work and planting	$780	$2,880	$5,070	$585	$11,970	$1,950	$2,550	$ 165
Fertiliser	$1,358	$5,221	$11,109	$1,354	$12,624	$2,651	$ -	$307
Crop Care	$1,736	$1,308	$16,808	$ 2,074	$21,555	$3,275	$1,136	$742
Irrigation	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Casual Labour	$ -	$ -	$ -	$ -	$ -	$ -	$ -	$ -
Harvest	$5,488	$ -	$4,966	$ 573	$17,850	$5,100	$975	$235
Post- harvest	$ -	$ -	$403	$46	$ 651	$155	$ -	$ -
Other	$10	$ -	$874	$112	$968	$202	$96	$25
Total Variable Costs	$10,032	$10,319	$41,767	$5,038	$71,812	$14,173	$7,570	$1,503

Table C28: Earnings Before Interest and Tax (EBIT)

Farm Revenue (Cropping Enterprise)	
Grains	$307,017
Forage	$51,600
Seed Crops	$16,775
Total Crop Revenue	$375,392
Farm Variable Costs from gross margins for all crops	
Seed	$14,279
Ground work and planting	$25,950
Fertiliser	$34,622
Crop Care	$48,634
Irrigation	$ -
Casual Labour	$ -
Harvest	$35,187
Post-harvest	$1,255
Other	$2,286
Total Variable Costs	$162,214
Fixed Costs	
Communications	$1,464
Accountancy	$2,091
Legal and consultancy	$1,255
Other Admin	$1,673
Rates	$3,974
Insurance	$6,274
Water charges	$ -
Other expenditure	$2,928
Total Fixed Costs	$19,659
Total farm working expenses before personal drawings	$181,873
Wages of management	$75,000
EBIT (Cropping Enterprise)	$118,519
EBIT (Cropping Enterprise/effective hectare)	$1,185

4.3. Nitrogen Inputs Mitigation

In this section, the financial analysis from the previous section are used to model restricting nitrogen fertiliser use (nitrogen inputs into the production system) as a mitigation for nitrogen loss. The modelling focused on restricting the use of nitrogen fertiliser (nitrogen inputs) because most mitigations in OVERSEER, such as reducing the length of the pasture phase or changing stock class, directly relate to the management of the stock on the farm. This section builds on the nitrogen mitigation modelling for Farms 1 and 2 in Section 0.

The modelling was done for a simple cropping enterprise to show the impact of restricting nitrogen inputs for Southland's two main arable crops: wheat and barley. It was limited to wheat and barley because information on the response of crop yield to the supply of nutrients was available. This information is needed to estimate the impact of restricting nitrogen fertiliser on gross margins. In other words, the financial costs of fertiliser use mitigations cannot be modelled without this information.

In general, restricting the use of nitrogen fertilisers (nitrogen inputs) is likely to eventually have a direct impact on crop yield. Perhaps not initially, as nitrogen from the soil supply is still available for the crop, but over time the soil supply will become depleted and crop yields will decline, impacting negatively on the annual income from the farm business. The value of integrated stock and arable enterprises is in maintenance of the supply of soil nitrogen through the mineralisation processes that occur with the rotation between pasture and cropping phases[27]. However, it is this mineralisation process that is a key driver of nitrogen losses from an arable farm.

4.3.1. Nitrogen Inputs Modelling and Results

The modelling was done on a 100 hectares cropping enterprise consisting of: 25 hectares feed wheat; 25 hectares milling wheat; and 50 hectares of spring barley.

As discussed above, the enterprise was limited to these crops, out of the range included in the Southland model arable farm, because there was reliable information on the yield response to nutrient supply. Together, wheat and barley represented 71% of the arable crops grown in Southland in 2011 (29% and 42% respectively).

The mitigation modelling for this simple cropping enterprise was done in two steps:

Step 1: Crop Yield Response: the crop yield responses for each crop were modelled in relation to changes in nitrogen inputs.

Step 2: Nitrogen Loss: the results of this crop yield response were then modelled in OVERSEER to show changes in nitrogen loss for different levels of nitrogen inputs.

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[27] Information relating to crop nitrogen demand for wheat and barley has been sourced from the FAR publication: "Cropping Strategies – Nitrogen Application in Wheat and Barley"(http://www.far.org.nz/mm_uploads/N_Cereals_strategy_issue_4_-_Final.pdf)

Step 1: Crop Yield Response

A gross margin analysis was completed for each of the three crops (milling wheat, feed wheat and barley) with a yield range of 1 to 12 tonnes/hectare for the two wheat crops, and a range of 1 to 10 tonnes/hectare for the barley. The modelling exercise was done to these limits because 12 tonnes for wheat and 10 tonnes for barley are representative of average yields for these crops in Southland. However individual farmers consistently achieve higher yields than these. In 2010 a Southland farmer held the wheat yield record of nearly 16 tonnes/hectare, which is an indication of the productive capability of Southland's soils and climate for grain crops.

For the simple cropping enterprise, it was assumed that:

1. The crop yield response directly related to the supply of nitrogen to the crop.
2. The soil supply of nitrogen for the crop was 25% of the crop requirement and the balance was supplied as urea fertiliser (urea is a manufactured organic fertiliser that has a high quick release of nitrogen).
3. The only cost in the gross margin analysis that varied related to the fertiliser application, both amount applied and number of applications. All other inputs stayed the same.

Table C29 and Figure C88 summarise the modelling of the yield response to a range of nitrogen inputs (from no limit to 50 kg N/ha). The change in EBIT relates to the change in income from the crop yield as it responds to the restriction on nitrogen and the reduced input cost for fertilisers and harvesting.

Table C29: Crop yield response results

	Wheat	Barley	EBIT/ha
No nitrogen input limit (216 kg N/ha)			
Applied urea (kg/ha)	470	375	
Yield	12 tonnes/ha	10 tonnes/ha	$3,692
Bales	18	9	
Nitrogen input limited to 140 kg N/ha			
Applied urea (kg/ha)	313	300	
Yield	8 tonnes/ha	8 tonnes/ha	$2,411
Bales	18	7	
Nitrogen input limited to 100 kg N/ha			
Applied urea (kg/ha)	235	225	
Yield	6 tonnes /ha	6 tonnes/ha	$1,566
Bales	14	5	
Nitrogen input limited to 50 kg N/ha			
Applied urea (kg/ha)	117	113	
Yield	3 tonnes/ha	3 tonnes/ha	$314
Bales	8	3	

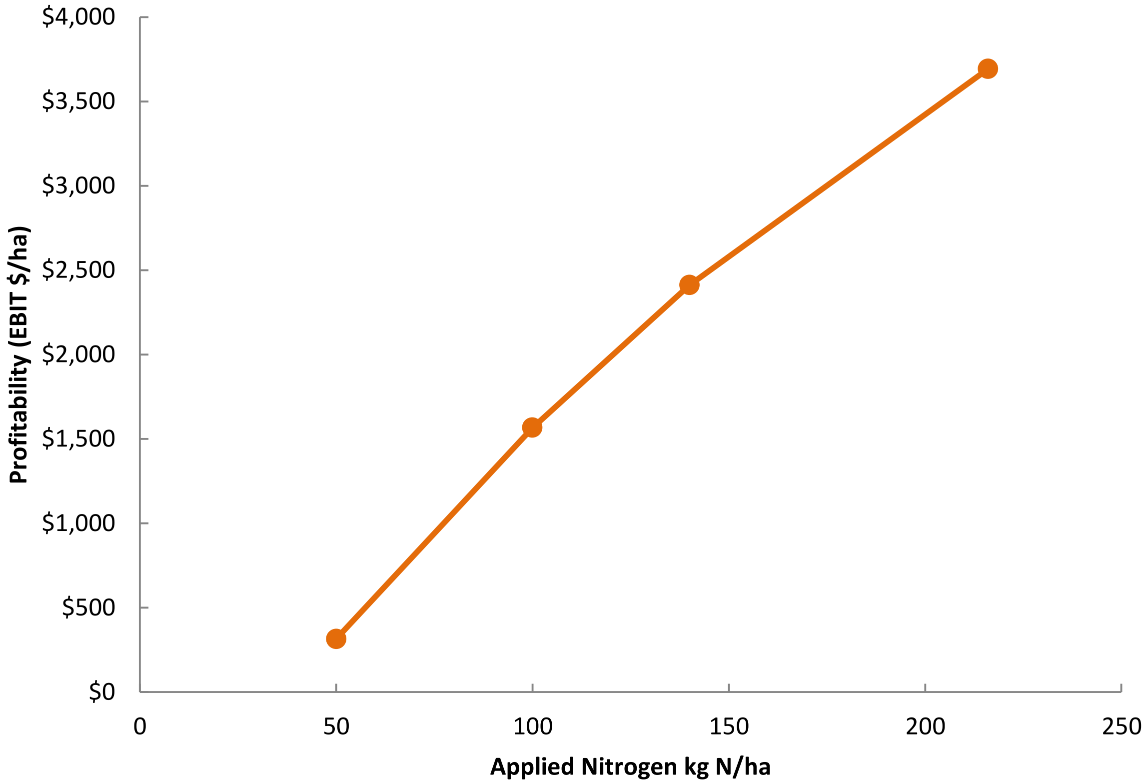

Figure C88: Change in profitability in response to a restriction on nitrogen inputs

Step 2: Nitrogen Loss

The yield responses of each crop to the supply of nitrogen (nitrogen inputs) were then modelled in OVERSEER. OVERSEER modelling for arable farm systems requires a two year period of the rotation and the model uses information differently each year. In Year 1 information is used to determine an estimate of soil supply of nitrogen; and in Year 2 information is used to predict nitrogen losses.

For the simple cropping enterprise, it was assumed that the rotation modelled was a grazed, rye grass seed crop in Year 1 followed by either wheat or barley in Year 2. This rotation is shown in Table C30. It was also assumed that the soil type is a moderately well-drained Kaweku silty loam over clay; annual rainfall was 840 mm; the ryegrass seed crop was managed with the standard good management practice fertiliser programme and grazed in winter by sheep; and the paddocks were left fallow (i.e. no crops planted) for some months.

Table C30: Rotation pattern over 2 years

April – January	Feb	March - August	Sept – Feb	March
Ryegrass seed crop grazed over winter, harvested in January	Fallow	Winter wheat		Fallow
Ryegrass seed crop grazed over winter, harvested in January, re-grazed in winter		Fallow	Spring barley	Fallow

Table C31 gives the crop rotation patterns and the nitrogen loss results. The block history has 0 years in pasture (i.e the rotation is a crop rotation with no pasture phases).

Table C31: Nitrogen loss modelling results

Crop Yields (Tonnes/ha)			Profitability	OVERSEER nitrogen loss
Feed wheat	Milling wheat	Barley	EBIT / eff. ha	Kg N/ha/year
1	1	1	-$531	20
2	2	2	$124	18
4	4	4	$737	17
6	6	6	$1,566	17
8	8	8	$2,411	17
10	10	10	$3,223	18
12	12	10	$3,692	18

Figure C89 summarises the change in nitrogen loss and profitablity with respect to limiting the use of nitrogen fertiliser (nitrogen inputs mitigation).

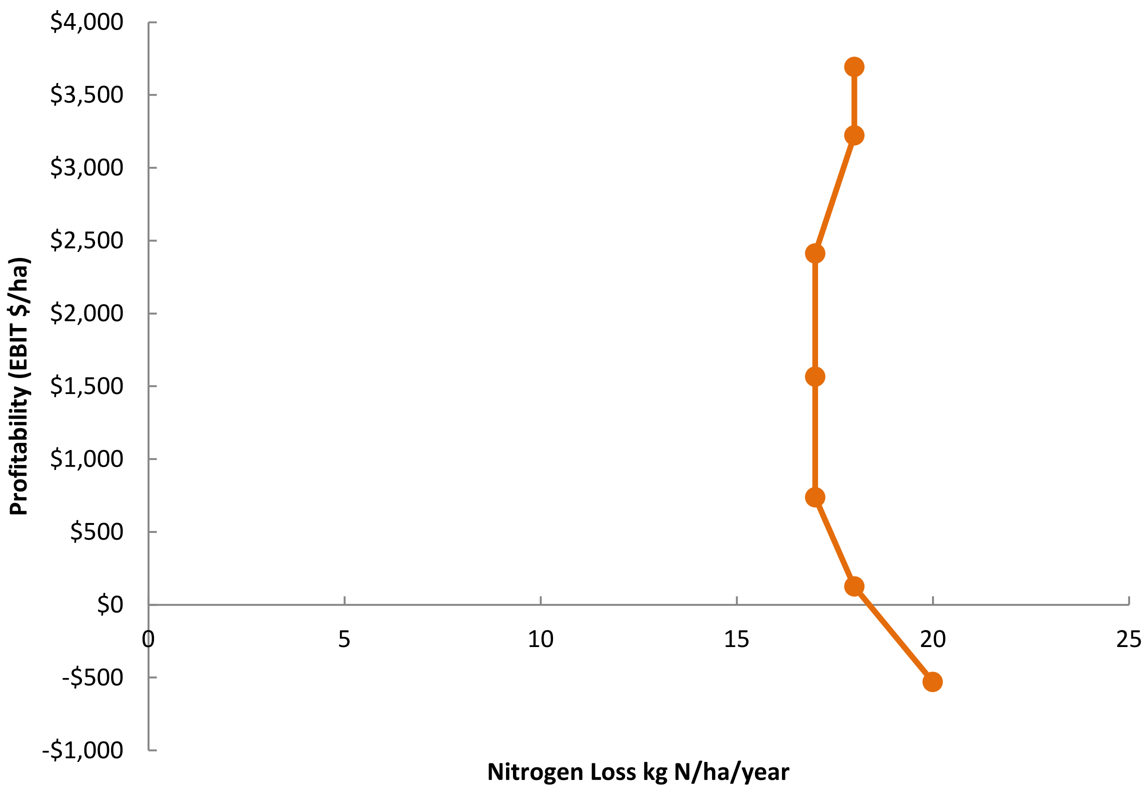

Figure C89: Change in nitrogen loss and profitability from nitrogen inputs mitigation

The fertiliser management for the arable grain crops in the crop yield response and nitrogen loss modelling is based on the recommended rates from FAR's crop yield response trials for wheat and barley. By following these input recommendations, there is a reduced risk of nitrogen losses where nitrogen has remained in the soil after harvest; irrespective of whether it is was a 20 tonnes or 10 tonnes crop being managed. This is because nutrient was supplied to meet crop demand.

OVERSEER's crop algorithms (mathematical formulas) follow the agronomic crop response curves for the crop being modelled. These curves indicate the relationship between crop yield and nutrient supply, in this case nitrogen, and have been developed through scientific measurement across a range of NZ soils and climates. Bearing this in mind, it is not surprising that the predicted losses over the range of crop yields modelled in OVERSEER are very similar, ranging from 20-17 kg N/ha/year. The nitrogen inputs for the crop are in line with the actual yield demand, and not supplied in excess. The soil supply for the scenario modelling was estimated to be 25% of the total crop demand. The applied fertiliser was the balance between the crop demand and the soil supply.

The crop yield response modelling shows that restricting nitrogen inputs will have a direct effect on crop yield and a negative impact on the profitability of the system.

The nitrogen loss modelling shows that a range of crop yields for both wheat and barley managed by accepted good management practice for nutrient supply, i.e. applying nutrients to match, but not exceed, the expected crop demand, have very similar nitrogen loss figures. Nitrogen loss only increases if fertiliser is applied in excess of the crop demand. These principles of nutrient supply apply to all crops, including pasture grasses.

The results indicate that a restriction on nitrogen inputs will have a direct negative impact on the profitability of arable enterprises because yields will be constrained. The results also indicate that restricting nitrogen inputs do not necessarily reduce nitrogen loss. Reductions in nitrogen loss only come about when farmers understand the dynamics of the nitrogen cycle, particularly mineralisation processes and the supply of nitrogen from the soil, and are able to match their fertiliser applications to the crop demand accordingly.

5. Horticulture

Summary Points

Tulip bulb and vegetable growing are incorporated into, and managed in together with, sheep farming in Southland.

There are few mitigations for horticulture that can be modeled in OVERSEER.

Yield is not only measured in weight but quality of the product as market requires a certain quality and size of vegetable and tulip bulb.

Authors: Stuart Ford (Director), **Agribusiness Group**, Angela Halliday (Manager, Natural Resources and Environment), **Horticulture New Zealand**; and **Environment Southland** staff.

5.1. Case Study Farm Selection

Both the vegetable and tulip industries in Southland are made up of a few large operators who are highly competitive within their own industry. For the case study modelling, Horticulture New Zealand surveyed a total of four vegetable and tulip bulb growers: the two main vegetable growers in Southland and two of the five growers of tulips. This survey information was used to develop three model farms: two vegetable farms, each with a different vegetable rotation on it, and one tulip farm with a tulip rotation on it.

The four growers who participated in the survey represent significant proportions of each industry. Roughly 90% of growing area in Southland is represented in this survey. The survey was carried out using an initial questionnaire, which was emailed to the four growers taking part in the survey to complete, and then followed up with a telephone interview.

The model farms developed from the survey information indicate average performance of the horticulture and tulip industries, rather than any individual operator. Likewise, because of the confidential nature of much of the information gained, particularly relating to financial performance, individual information is not explicit in the results of this report. For the tulip bulb growers, much of the data in terms of physical parameters is an average for the crops represented (i.e. not an exceptionally good or bad year).

The survey information covered:

1. Generalised crop rotation – for both owned and leased land;
2. Irrigation practices;
3. Crop management – growth period, area, crop yield, fertiliser type and volume and timing of applications, crop residue management etc.;
4. Animal management;
5. The use of both good and best management practices; and
6. Gross margin information on the crops, which has been converted into whole farm financial information to be comparable with the case studies from other industries.

For commercial reasons outlined above, ‘typical’ rotations were developed for OVERSEER using the base information that growers provided. Each rotation was modelled on a corresponding farm: one model farm to represent production of carrots and potatoes, one model farm that represents parsnip production, and one model farm for tulip bulb production.

5.2. Baseline

Using the model farms and the ‘typical’ rotations for Southland, the modelling was carried out in two stages: the modelling of the farming systems in OVERSEER and the financial analysis of the farm operations.

The crops were modelled using a whole farm system approach to show the impact of a crop over its entire rotation on a piece of land, rather than the losses of the crop in the one year it is grown out of the rotation. This approach is consistent with OVERSEER modelling for horticulture in other regions. A whole farm (full rotation) representative OVERSEER file was created for each of the model farms. The size of the farm used in the representative file was driven by the size a farm would be required for the crops to adequately rotate around the property.

5.2.1. OVERSEER Modelling

Each of the two vegetable model farms consisted of 300 hectares for a vegetable rotation and the tulip bulb model farm consisted of 120 hectares for a tulip bulb rotation, based on the size needed for each rotation.

The vegetable and tulip bulb rotations that were modelled ran as follows:

Carrot Rotation (total length: 12 years)

Pastoral (9 years) > Potato Year 1> Carrot Year 2> Carrot Year 3> Re-grassed.

Parsnip Rotation (total length: 12 years)

Pastoral (9 years) > Barley Year 1> Parsnip Year 2> Parsnip Year 3> Re-grassed.

Tulip Rotation (total length: 13 years)

Pastoral (12 years) > Tulips Year 1> Re-grassed.

On each model farm, the size of each crop block modelled is 10 hectares with the rest being in pasture with sheep. This means that for the two vegetable rotations (carrot and parsnip) there are 20 hectares of each crop grown on the property at one time because the crop is grown in successive years.

It was not possible to model tulip bulbs in OVERSEER because this crop is not available as an option so onions were chosen as an alternative crop to model on the advice of Dave Wheeler (AgResearch). The onion crop was set up to require nutrients from the soil for the same period as tulips require them and then to dry off and “senesce” (an aging or maturing process) at the same time as tulips do. This crop is considered to be fairly reasonable portrayal of tulips in Southland.

All OVERSEER modelling has been carried out so that it conforms to the *Best Practice Guidelines for Data Entry for OVERSEER*. The soil type which was chosen was a Waikiwi soil type with all data taken from S-Map. This soil type was modelled because it is the most common soil type on which these crops are grown in Southland.

5.2.2. Financial Analysis

The financial analysis was set up to be consistent with the MPI Farm Monitoring Model: Southland South Otago Intensive Finishing Sheep and Beef farm model. The MPI Farm Monitoring has not been updated since 2012 so the expenditure information was inflated by 1.5% per year to bring it up to date. The income items used were gained from the *Situation and Outlook for Primary Industrie*s report (MPI, 2015g). MPI reports national average prices paid for livestock production for the previous four years and expectations of the likely returns in each of the next four years. The average of these reports of actual and predictions for the future were used in the financial model. These averages are shown in Table C32.

Table C32: Pastoral commodity prices used in the financial model

	$ / Kg
Lamb Price	5.68
Beef Price	4.41
Wool Price	6.29

The financial data gained from the growers' survey (in the form of gross margins) was put into the same format as the financial analysis and each part of the rotation was weighted up according to its area to calculate the performance for the farm as a whole.

To avoid the build-up of pathogens in the soil and to maintain soil structure root vegetables and tulips generally rotate around sheep farming enterprises in Southland. The survey data from growers for the crop information and MPI for the other enterprises was used for the report. Roughly 80% of land used for horticultural crops is leased from sheep and beef farmers in the areas with suitable soils for growing.

5.3. Baseline Results

The baseline results display the modelled nitrogen losses from a representative, whole farm (full rotation) OVERSEER file (kg N/ha/year). Baseline phosphorus losses are not reported; as OVERSEER cannot fully represent the advanced technologies that horticultural growers currently use to mitigate phosphorus losses.

The baseline results for nitrogen loss from the OVERSEER modelling are shown in Table C33.

Table C33: Nitrogen results of OVERSEER modelling (kg N/ha/year)

	Carrot rotation	Parsnip rotation	Tulip rotation
Pastoral	9	10	9
Potato	71	-	-
Barley	-	125	-
Carrots Year 1	99	-	-
Carrots Year 2	40	-	-
Parsnips Year 1	-	80	-
Parsnips Year 2	-	61	-
Tulip Bulbs	-	-	134
Whole Farm	**15**	**18**	**19**

A summary of the financial analysis for the three rotations are shown in Table C34. It is not possible to report on prices for each crop and yields because of confidentiality issues resulting from the small number of growers in Southland.

Table C34: Financial analysis of the three rotations ($/ha)

	Carrot	Parsnip	Tulip bulb
Gross Revenue	8,387	13,800	9,455
Farm Working Expenses	5,763	4,972	4,043
Cash Operating Surplus	2,624	8,827	5,411

5.3.1. Carrots

The carrot rotation starts with pasture, which has a leaching figure of 9 kg N/ha/year. The ground is then conventionally cultivated and a paddock of potatoes which have a nitrogen loss rate of 71 kg N/ha/year. Although this figure is high, it is not as high as the crops grown in the first year out of pasture in the next two rotations because with potatoes more of the crop is harvested. It is an indication of the very high mineralisation of nitrogen that occurs with the cultivation of the paddocks that have previously remained in pasture for over ten years. The nitrogen losses for the two years in carrots indicate a high mineralisation of nitrogen. In both years the carrots are both treated exactly the same in the modelling but have nitrogen loss figures that reduce from 99 kg N/ha/year in the first year to 40 kg N/ha/year in the second year. The whole farm (full rotation) nitrogen loss rate result for the carrot rotation is 15 kg N/ha/year.

5.3.2. Parsnips

The parsnip rotation starts with pasture, which has a loss rate of 10 kg N/ha/year[28]. This is followed by barley, which has a nitrogen loss rate of 125 kg N/ha/year. This result is high because of

[28] It is thought that the pasture leaching rate for this rotation differs slightly than that for other rotations as a result of OVERSEER rounding to the nearest kilogram (Angela Halliday, pers. comm., 2016).

cultivation following a long period in pasture and less of the crop is harvested, compared with potatoes in the first rotation. The parsnips have a lower result than barley, with 80 kg N/ha/year for the first year and 61 kg N/ha/year for the second year. The reduction in nitrogen losses between years again is indicating the mineralisation of nitrogen. The whole farm (full rotation) nitrogen loss rate result for the parsnips is 18 kg N/ha/year.

5.3.3. Tulip Bulbs

The tulip bulb rotation starts with pasture having a leaching rate of 9 kg N/ha/year. The pasture is followed by tulips, which have a nitrogen loss result of 134 kg N/ha/year. The whole farm (full rotation) nitrogen loss rate result for the tulip rotation is 19 kg N/ha/year.

5.4. Mitigation Scenarios

There are a number of issues related to horticulture production that result in high nitrogen losses and inefficient nitrogen use when compared to pastoral land uses. However, many horticulture growers have continued to refine their use of nitrogen inputs, which has resulted in reductions in the use of nitrogen per hectare, and therefore the total amount of nitrogen loss over time (Stuart Ford, pers. comm., 2015).

For horticulture, the major source of nitrogen loss is derived from fertiliser and crop residue. Fertiliser nitrogen management strategies, specifically timing and volume of nitrogen application are key when devising mitigations (Menneer, Ledgard, & Gillingham, 2004).

In general, the main factors responsible for nitrate leaching in horticultural systems are (Di & Cameron, 2002): high nitrogen use (fertiliser and manure), frequent cultivation, relatively short periods of plant growth, low nutrient use efficiency by many vegetable crops; and crop residues remaining after harvest.

Vegetable crops have sparse root systems in the early stages of their growth that are inefficient at recovering applied fertiliser so relatively high application rates of all fertilisers are used to maximise growth. Vegetables typically have short growing periods and also are grown over winter when plant growth and nitrogen uptake is slow (Haynes, 1997; Haynes & Francis, 1996).

The recovery of applied nitrogen by vegetable crops is often less than 50%, and can be as low as 20% (Di & Cameron, 2002). As a result, a large quantity of fertiliser nitrogen remains in the soil surface layers and is susceptible to leaching during rainfall or irrigation. Following crop harvest large amounts of plant residues are usually incorporated into the soil which, following decomposition, release mineral nitrogen into soil. The amount of mineral nitrogen derived from fertiliser and crop residue present in the soil after harvest can be as high as 200-300 kg N/ha/year, and is the major source of leached nitrogen. Fertiliser nitrogen management strategies are the key to nitrate leaching intervention in these systems.

There are three main issues causing nitrogen loss in vegetable growing operations in Southland. Crops have short growth periods and therefore (in some cases) multiple crops are grown in one year (and the resulting cultivation of the soil). Crops are grown over winter when leaching rates are high because of high rainfall and saturated soils and there is less nutrient uptake by the crop due to lower temperatures. Also, crop residue is left in the paddock after harvest, which is worked into the soil.

The situation for most horticultural crops in Southland is that they are rotated around pastoral land (usually sheep farms). Once a paddock has been cropped for one or two years the paddock returns to pasture for ideally the next ten years and another paddock is bought in from pasture and cropped for one to two years. It means that the paddock has relatively high nitrogen losses (compared with pasture) for the year the crop is grown but not over the full rotation of a farm. Similar to arable enterprises within pastoral systems, the rotational nature of horticulture is a significant factor when assessing nitrogen losses.

5.4.1. Nitrogen Mitigations

Background research suggests that the mitigation options available to vegetable growers are based around improving nutrient use efficiency. These mitigation options include:

1. Nutrient management planning;
2. Proper fertiliser material selection;
3. Better application timing and placement; and
4. Improved irrigation scheduling.

Slow release fertilisers can be used to mitigate nitrogen losses because they act as a retardant to nitrogen loss and are a potential mitigation option. However, there are certain times when vegetable crops have a very high nitrogen demand and slow release fertilisers would not be able to adequately meet the crops' requirements. Also, it is not yet possible to model slow release fertilisers at present in OVERSEER. As a result, slow release fertilisers were not modelled as a mitigation.

Analysis of the growers' current mitigation practices in Southland showed they carry out nutrient management planning, fertiliser material selection, and that technology has improved their timing and placement of nitrogen application. However, growers are limited by the type of system they can use to improve the scheduling of irrigation. This analysis showed the major impacts on nitrogen losses related to both the amount and timing of applications of nitrogen. Therefore, mitigations relating to nitrogen application practices, as outlined in the next section, were tested in the modelling.

Modelled Mitigation 1 – Limiting nitrogen fertiliser application

One mitigation option is to limit any one application of nitrogen to 80 kg N/ha per month (the 80 kg level relates to the early spring minimum requirements). However, none of the growers applied nitrogen at a rate higher than 80 kg N/ha/year so this mitigation technique was not modelled for horticultural crops and tulips in Southland. This situation was partly driven by the regular nitrogen applications that are made in horticultural crops and the smallest window of applications in OVERSEER is on a monthly basis. Current best practice is for the application of nitrogen to be more regular than once per month, particularly in the early growing stages when the plants are small, growing rapidly and have a high requirement for nitrogen. There is also the requirement to apply nitrogen early in the growth phase of many of the crops experience shows that later applications of nitrogen can lead to reduced yield and deterioration in crop quality as a result of being pushed along later in their maturity.

Modelled Mitigation 2 – Altering the amount of nitrogen fertiliser and the yield

This mitigation option reduced the amount of nitrogen applied to the crop in -10% steps up to -30% total reduction. The modelled reductions in yield were based on research on the impact of nitrogen on yield and informed by the experience of some growers in the Pukekohe District (Obreza & Sartain, 2010; Pearson, Renquist, & Reid, 1999; Wood, 1997; Wood, 1998; Sher, 1997; Ministry of Agriculture and Forestry, 1979). The yield reductions were then ground-truthed with growers in Southland. The impact of reduced nitrogen on the tulip bulbs was taken from an estimate made by the growers in Southland. The assumptions for average yield reduction by individual crop are shown in Table C35. For horticulture, yield is only measured at harvest and a reduction in size and quality of a product is actually more important than yield itself.

Table C35: Yield reduction as a result of a reduction in nitrogen application (%)

	-10% Step	-20% Step	-30% Step
Carrot and Potato	10%	20%	30%
Parsnip	10%	20%	30%
Tulip Bulb	7%	14%	25%

Many of the research reports referenced for the Pukekohe District refer to trials that occurred from the mid-1960s to the late 1980s. During this time period the amount of nitrogen used was much higher than it is now. Although little research has been carried out more recently into nitrogen use on horticultural crops, many growers have continued to develop their knowledge on timing and volume of nitrogen application to maximise crop growth and to improve nitrogen use efficiency and reduce costs. This change in practices has resulted in much lower rates of nitrogen usage than those quoted in these research reports.

Mitigations Not Modelled

Cover Crops

The use of cover crops is a useful mitigation technique for reducing the amount of nitrogen that leaks through the soil profile, particularly during winter months when there is high rainfall and the soil is generally saturated. Cover crops used in other parts of New Zealand include mustard, oats and ryegrass. Based on the survey information, it was found that the use of cover crops was already wide spread in Southland and cover crops were used on the vegetable model farm. As a result, it is not generally a mitigation option available to the growers.

Active Water Management

This mitigation option was initially chosen to test the impact of altering irrigation practices. As a result of the information gained from the survey, it was clear that the growers in Southland only use irrigation occasionally when soil moisture testing shows it is necessary. Therefore altering irrigation practices is not a mitigation option available to the growers.

Altered Tillage Practices

The amount of tillage applied to the soil releases more nitrogen as tillage increases. In horticultural operations in Southland there is a high degree of tillage required to get the soil into a sufficient state to plant some crops and to be able to form the beds which many of the crops need to be grown on. Therefore altering tillage practices is not a mitigation option available to the growers.

5.4.2. Phosphorus Mitigations

Over the last fifteen years or so Horticulture NZ has developed a wide range of techniques specifically designed to control the amount of soil erosion and sedimentation of soil from cultivated land. There is a project currently underway that aims to quantify the effectiveness of these techniques to help growers with decision-making and paddock risk assessment. These techniques are effective in reducing the loss of phosphorus from run off and include activities such as: aligning cultivation practices with the angle of the paddock, earth bunding, and grassed swales[29]. Much of this work was carried out in the Pukekohe area but has been used in Horticulture NZ's *Code of Practice for Nutrient Management*[30] and is relevant to Southland, depending on the risk assessment of the paddock and location of waterways.

However, it is not possible to model the various techniques used in the Franklin District to manage the amount of soil movement, and so phosphorus, in OVERSEER. The amount of phosphorus loss reported from OVERSEER modelling only reflects the amount of phosphorus applied in fertiliser and the standard discharge rates assumed in OVERSEER. It is unknown whether the amount of phosphorus lost from horticultural properties is under or over-estimated because of the simplistic way it is modelled. The modelling results for phosphorus are not reported because they do not well represent the effectiveness of horticultural practices.

5.5. Mitigation Results

5.5.1. OVERSEER Modelling

Of the range of mitigations, there was only one option that is available to the growers in Southland and modelled in this research: to limit the amount of nitrogen fertiliser applied to the crop. This mitigation was modelled in OVERSEER and the nitrogen results are shown in Tables C36 to C38.

[29] In this context, earth bunds are humps of earth that stop run-off entering waterways and possibly direct it to sediment traps; and grass swales are areas intentionally left at the end of a row to filter sediment out of overland flow of water from paddocks.
[30] This is available on the Horticulture New Zealand website www.hortnz.co.nz under Natural Resources, Good Management Practice.

Table C36: Nitrogen results for mitigation modelling in carrot rotation (kg N/ha/year)

	Base	-10% Step	-20% Step	-30% Step
Pastoral	9	9	9	9
Potato	71	68	65	62
Carrot Year 1	99	94	88	83
Carrot Year 2	40	37	33	29
Whole Farm	15	15	15	14

Table C37: Nitrogen results for mitigation modelling in parsnip rotation (kg N/ha/year)

	Base	-10% Step	-20% Step	-30% Step
Pastoral	10	10	10	10
Barley	125	125	125	125
Parsnips Year 1	80	77	74	71
Parsnips Year 2	61	56	51	45
Whole Farm	18	17	17	17

Table C38: Nitrogen results for mitigation modelling in tulip rotation (kg N/ha/year)

	Base	-10% Step	-20% Step	-30% Step
Pastoral	9	9	9	9
Tulip	134	129	124	120
Whole Farm	19	18	18	18

These tables show that reducing the percentage of nitrogen fertiliser applied reduces the nitrogen loss from individual crops by up to 10% but does not reduce the whole farm nitrogen loss figures. Markets require certain size and quality for vegetables so while yield is one consideration for growers, quality and size are also important when planning nutrient requirements for crops. For example, the main market requirement for tulip bulbs is 12+cm, there is a reasonable market for bulbs 11-12cm circumference, and there is almost no market for tulip bulbs under 11cm circumference. To achieve a saleable grade requires an exact balance of moisture, temperature and nutrients.

5.5.2. Financial Analysis – Full Rotation

The financial results of the mitigation modelling are shown in Tables C39 to C41 (results are rounded to closest hundred). The results take into account the operating expenses of the whole farm, including both pastoral and crops. These enterprises do not work in isolation and are modelled as a whole system.

Table C39: Financial results for mitigation modelling in carrot rotation ($/ha)

	Base	-10% Step	-20% Step	-30% Step
Gross Revenue	8,400	7,700	7,000	6,200
Farm Working Expenses	5,800	5,600	5,500	5,200
Cash Operating Surplus	2,600	2,100	1,500	900

Table C40: Financial results for mitigation modelling in parsnip rotation ($/ha)

	Base	-10% Step	-20% Step	-30% Step
Gross Revenue	13,800	12,600	11,300	10,600
Farm Working Expenses	5,000	4,800	4,600	4,300
Cash Operating Surplus	8,800	7,700	6,700	5,800

Table C41: Financial results for mitigation modelling in tulip rotation ($/ha)

	Base	-10% Step	-20% Step	-30% Step
Gross Revenue	9,500	8,900	8,300	7,400
Farm Working Expenses	4,000	4,000	4,000	4,000
Cash Operating Surplus	5,400	4,900	4,300	3,500

It is not possible to report yield reduction in tonnes because of confidentiality issues resulting from the small number of growers. For the tulip bulb growers, the larger the bulb size the higher the return for the crop. The impact of a reduction in the amount of nitrogen fertilisers applied is that a higher proportion of the tulip crop slips into the lower size bulb grades that are able to be marketed. It means that both the total volume of crop is reduced as well as the fact that the average price received is reduced. Overall, the total amount of revenue received is reduced.

In general, the OVERSEER modelling and financial analysis shows:

1. The mitigations tested lead to considerable reductions in the financial results with little or no reduction in the amount of nitrogen leached across the whole farm results;
2. The current mitigations able to be modelled in OVERSEER are limited and have a limited effect on the reported nitrogen loss;
3. The results suggest the mitigation considerably reduces both the nitrogen leached from the horticultural crops and tulips within the full rotation, and the financial returns; and
4. The small change in the whole farm loss rate reflects the fact that the losses from the crop are diluted by the 9 to 12 years the land is in pasture and no mitigations are applied.

5.5.3. Mitigation Curves – Individual Crop

Figure C90 to Figure C92 show the baseline and mitigation results in terms of nitrogen loss and financial returns (using cash operating surplus) for the step reductions in nitrogen applied. In this case, the results are for the individual crop, rather than the full rotation.

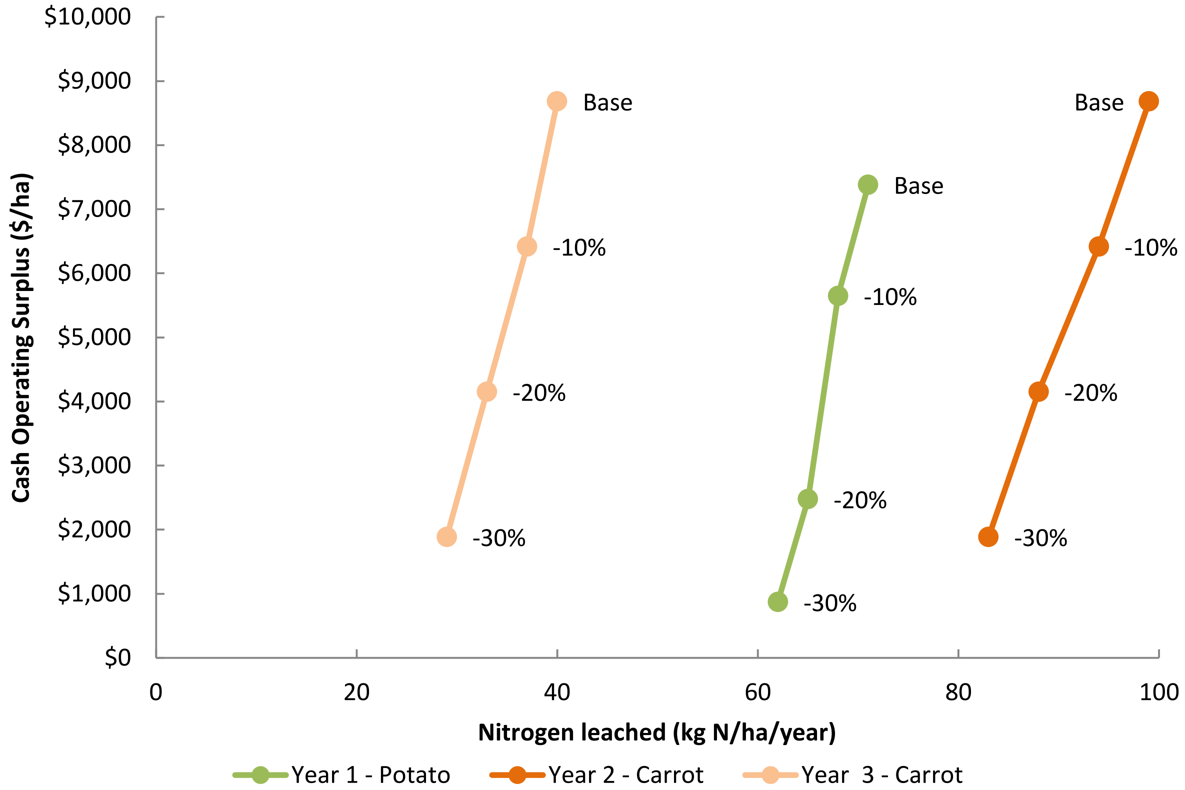

Figure C90: Nitrogen mitigation curves for potato and carrot rotations (years 1, 2 and 3)

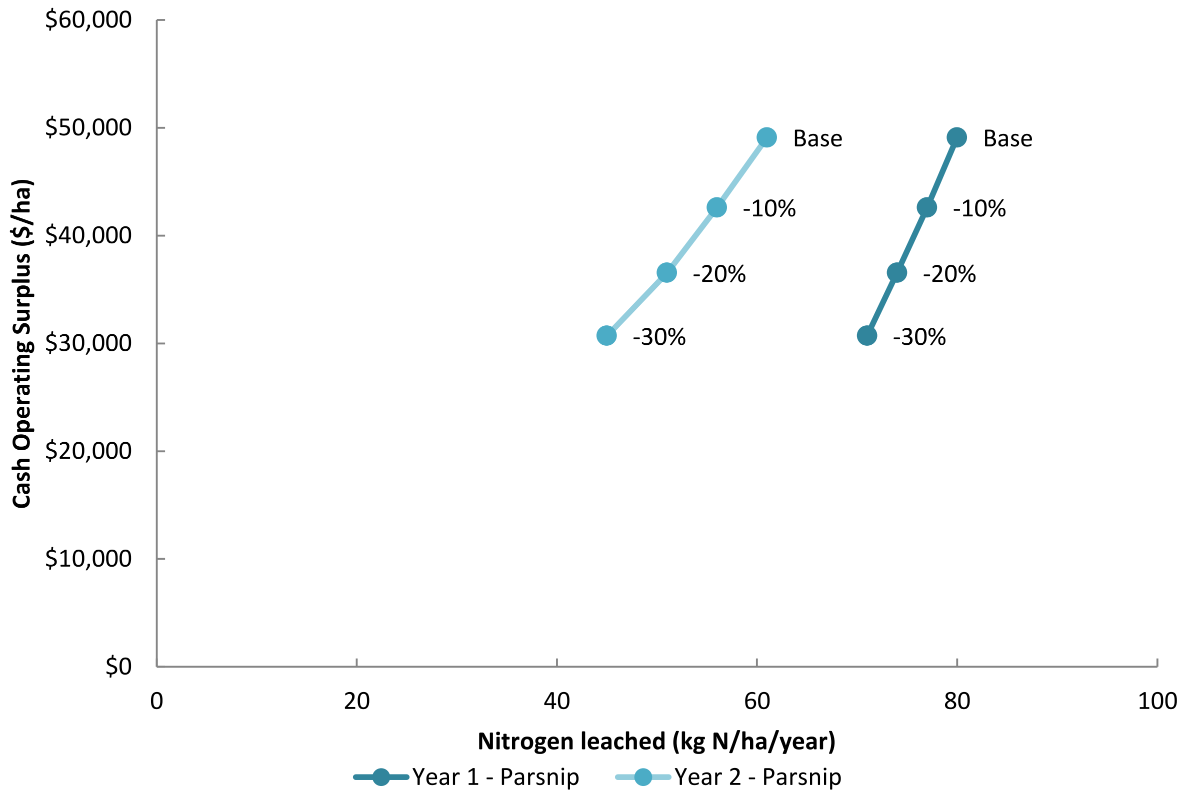

Figure C91: Nitrogen mitigation curves for parsnip rotations (years 1 and 2)

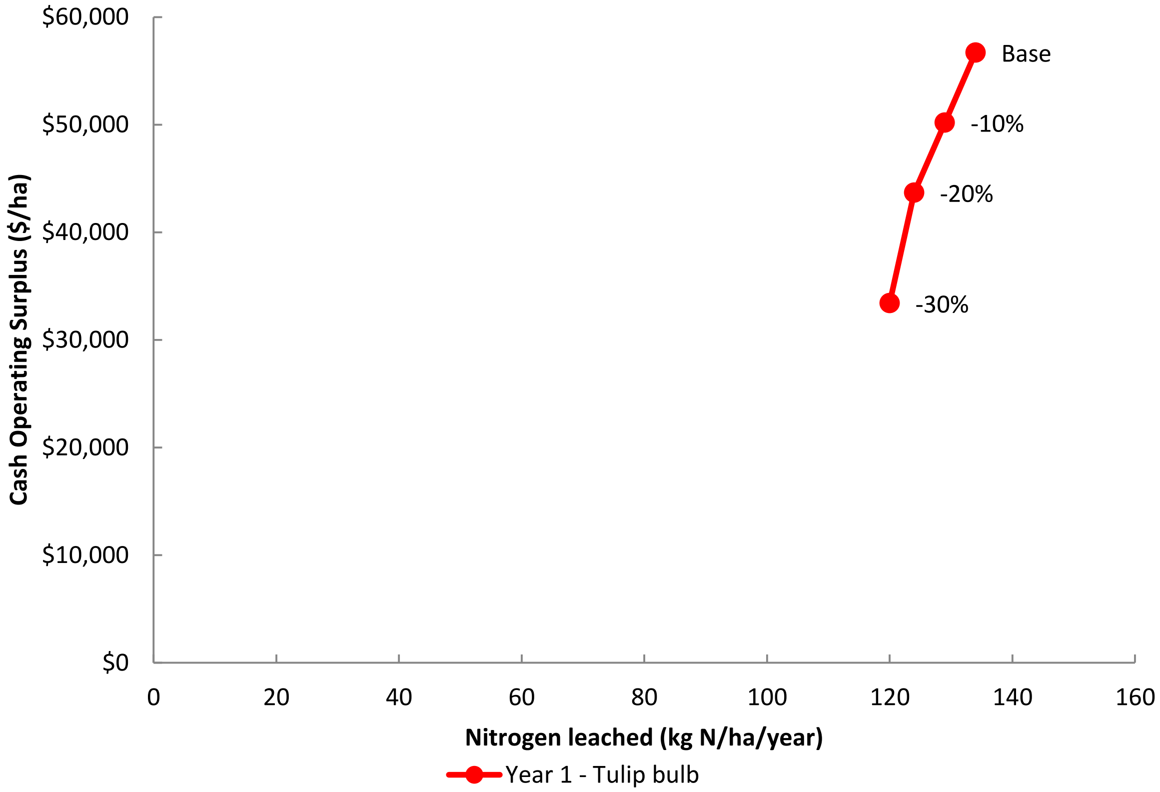

Figure C92: Nitrogen mitigation curve for tulip rotation

5.5.4. OVERSEER Modelling for Horticulture

Horticulture New Zealand supports of the appropriate use of OVERSEER as a risk assessment tool. However there are reservations that the cropping module at present is not robust enough to give reliable estimates of nutrient leaching rates to base regulations on for cropping rotations. The exercise is also expensive for an individual grower to carry out. Horticulture New Zealand's aim is to have the capability to accurately predict the nitrogen loss performance of a property in a cost-effective manner. Research is currently being done to identify and address existing modelling anomalies and to develop the cropping module into a more robust tool.

Apart from the basic uncertainty around the accuracy of the crop module, there are also concerns about the accuracy of the results. The gross nature of the inputs used to enter data (monthly data is the shortest input timeframe) is unable to accurately reflect the complexities of vegetable rotations. Also, there is not the ability to model all crop types or the range of mitigations that are possible on vegetable properties. Plant & Food Research identified that, in the crop modelling exercise for the Matrix of Good Management Project in Canterbury, approximately half of the crops sown were not options in OVERSEER (Hume, Brown, Sinton, & Meenken, 2015).

While the principles for resolving the limitations of OVERSEER modelling of crop blocks apply to both the horticultural and arable industries, most of the issues identified were more specific to the horticulture because of their dynamic management and rotation structures. If growers are to use OVERSEER for nutrient budgeting, they will need guidelines and expectations for the modelling of their farms to ensure consistency of outputs across the industry.

6. The Southland Economic Model for Fresh Water

This report has presented research that was undertaken by industry groups as part of The Southland Economic Project. Through this research, a set of case study farms have been produced for each agricultural industry. This agricultural dataset will be used in The Southland Economic Model for Fresh Water, which has also been developed within The Southland Economic Project. In essence, this dataset will be used in the future to understand the possible economic impacts of achieving limits for all farms in Southland.

The Southland Economic Model is a model of all sectors in the economy, and it breaks agriculture down into its industries to give more resolution. For agriculture, the model contains component parts for geographic areas across Southland: Te Anau Basin, Lower Waiau, Aparima, Ōreti, Lower Matāura and Northern Matāura. The model traces the stocks and flows of resources (for all types of capital and labour) within Southland, and between Southland and the rest of New Zealand. In tracing resources through the economy, the model will have the capability of reporting on both direct impacts (as felt by the business owners) and wider impacts (those that flow-on through value chains, consumer spending and pricing).

Image C2: Waimea Plains and the 'Hokonuis', Northern Matāura
Source: Lisa Pearson

The model will be used to build understanding of possible economic impacts by testing a range of ‘what if’ scenarios and comparing the results to a baseline scenario, which will describe what could have happened otherwise. The results will be produced at a number of different scales, including: specific sectors, local economies (e.g. Invercargill, Gore, and Te Anau), territorial areas, the region and the rest of New Zealand. These results will be reported using several economic measures to give a multi-dimensional picture. Key measures will be changes in employment, household income, and economic growth. The model will also include the ability to change certain factors, such as commodity prices, to measure how changes these factors could influence the results.

Importantly, The Southland Economic Model for Fresh Water is ‘dynamic’, which means that it traces resources through time, as the economy moves from its start year in 2016 out 30 years to 2046. The model is calibrated using existing data that goes back to 2007. Because it is dynamic, the model will show how Southland’s economy could evolve or transition to a new water and land management system under different scenarios. These ‘transition pathways’ will allow people to see the possible economic impacts of different rates of change, both in policy implementation and behavioural response (i.e. adoption of mitigations). The start year for the model is 2016 because this is the year when Environment Southland started its implementation of the National Policy Statement of Fresh Water in Southland.

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Appendices

Appendix 1: Southland Soils

The soil formation factors detailed in Section **Error! Reference source not found.**: Soils form the basis of the New Zealand Soil Classification (NZSC). The NZSC is based on a four-tier hierarchical structure for Order > Group > Subgroup > Soilform (parent material, rock class and particle size) (Clayden & Webb, 1994; Hewitt, 2010). This report focuses on the NZSC Soil Orders for Southland soils. Table 1 shows how the soil orders are related – note: it is not a formal part of the NZSC but merely a means to help understand the relationship between soil orders. The seven main soil orders found in Southland are highlighted in bold in Table 1.

Soil information can be entered into the OVERSEER model in multiple ways, either through online soil maps (S-Map), by soil series (local name), by soil order or at the most basic by soil group.

Table 1: Organisation of New Zealand Soil Classification (NZSC) soil orders (Table from Hewitt , 2013).

Age	Key Factor	NZSC Order
Young soils		**Recent Soils** Raw Soils Anthropic Soils
Mature soils *Soils that have well developed topsoil and subsoil horizons*	**Climate** *Soils formed in quartz rich materials that show the effects of climate*	**Brown Soils** **Pallic Soils** **Podzols** Semiarid Soils
	Wetness *Soils with prolonged high water tables*	**Gley Soils** **Organic Soils**
	Rock *Soil parent materials formed from rocks that dominate the soil character e.g. limestone, basalt pumices and volcanic ash*	**Melanic Soils** Pumice Soils Allophanic Soils
Old Soils		Ultic Soils Granular Soils Oxidic Soils

Soil maps for Southland were surveyed by DSIR (1968) to produce the Land Resource Inventory (also known as Fundamental Soil Information), and O'Byrne (1986) for the soils of Wallace County (in the Waiau). More recent soil mapping was undertaken on flat to rolling agricultural land (at a scale of 1:50,000) as part of the Topoclimate South Soil Mapping Project (2001). This scale is capable of identifying significant soil variations at the farm level, which is sufficient for most land users. The Topoclimate South map is available on Beacon (an interactive GIS tool) on Environment Southland's website[31]. Environment Southland uses a combination of these soil maps to produce regional maps incorporating the most recent information. These maps can be used to determine the necessary soil information to incorporate in OVERSEER modelling.

Table 2: Southland Soils

Soil Name	Area (ha)	NZSC Order	NZSC Group	NZSC Subgroup	Profile Material	Particle Size	Drainage class
Acton	702	Gley	Orthic	Melanic	Stoneless	silty	Poor
Alton	849	Recent	Fluvial	Mottled	Stoneless	silty	Imperfect
Andrews	508	Organic	Mesic	Acid	Deep (Sd)	peat	Very poor
Aparima	14556	Brown	Firm	Mottled-acidic	Stoneless	silty	Imperfect
Ardlussa	6701	Brown	Orthic	Pallic	Stoneless	silty	Well
Arthurton	12131	Brown	Firm	Mottled-acidic	Stoneless	silty	Imperfect
Ashers	551	Podzol	Pan	Firm	Stoneless	silty	Imperfect
Ashton	72	Brown	Orthic	Acidic	Rounded stony	silty	Well
Athol	1960	Pallic	Perch-gley	Typic	Stoneless	silty	Poor
Benio	5069	Ultic	Yellow	Typic	Rounded stony	silty	Moderately well
Berwen	508	Pallic	Argillic	Typic	Angular-stony	silty	Well
Borland	93	Brown	Orthic	Acidic	Angular-stony	loamy	Moderately well
Braxton	19334	Gley	Orthic	Typic	Stoneless	clayey over silty	Poor
Caroline	6496	Gley	Orthic	Ironstone	Rounded stony	silty	Poor
Charlton	2378	Brown	Orthic	Mottled-pallic	Stoneless	silty over sandy	Imperfect
Chaslands	7131	Brown	Firm	Mottled	Stoneless	silty	Imperfect
Chatton	4089	Brown	Firm	Typic	Soils with stones	silty over skeletal	Moderately well
Chewings	689	Gley	Recent	Calcareous	Stoneless	clayey over silty	Poor
Clinton	2195	Brown	Firm	Typic	Stoneless	silty	Well
Clydevale	978	Pallic	Fragic	Mottled	Stoneless	silty	Imperfect
Colac	3094	Organic	Mesic	Mellow	Deep	Loamy peat	Very poor
Conical Hill	765	Melanic	Mafic	Typic	Rounded stony	silty	Well
Craigdale	655	Brown	Orthic	Acidic	Moderately deep /rock	silty	Well
Crookston	6122	Brown	Firm	Pallic	Stoneless	silty	Well
Dacre	12111	Gley	Orthic	Acidic	Stoneless	silty	Poor
Dipton	5001	Pallic	Perch-gley	Argillic	Rounded stony	clayey	Poor
Dome	338	Recent	Fluvial	Typic	Angular-stony	silty	Well
Drummond	3073	Brown	Mafic	Acidic	Soils with stones	silty over skeletal	Well
Edendale	9745	Brown	Firm	Typic	Stoneless	silty	Well
Excelsior	5632	Brown	Allophanic	Fragic	Soils with stones	silty over skeletal	Well
Fairfax	2857	Brown	Firm	Acidic	Stoneless	clayey	Moderately well
Ferndale	1653	Brown	Firm	Mottled-acidic	Stoneless	silty	Imperfect

[31] http://gis.es.govt.nz/index.aspx?app=topoclimate
For areas outside Topoclimate South coverage see the Fundamental Soils layer from Landcare Research – produced using the Land Resource Inventory (DSIR, 1968).
https://soils.landcareresearch.co.nz/maps/soilportal.html?Service=NZ&LayerSetName=FSL_NZSC_Layers&FromWhere=MAPSELECTION

Soil Name	Area (hectares)	NZSC Order	NZSC Group	NZSC Subgroup	Profile Material	Particle Size	Drainage class
Fleming	3051	Pallic	Perch-gley	Fragic	Stoneless	silty	Poor
Fortification	1226	Allophanic	Orthic	Acidic	Moderately deep /rock	clayey	Moderately well
Fortrose	1429	Brown	Firm	Mottled	Stoneless	silty	Imperfect
Freestone	727	Brown	Firm	Typic	Stoneless	loamy	Well
Glenelg	14848	Brown	Firm	Cemented	Rounded stony	silty	Well
Glenlea	665	Brown	Orthic	Acidic	Paralithic	silty over clayey	Moderately well
Glenure	3943	Gley	Orthic	Acidic	Stoneless	silty	Poor
Gore	17896	Brown	Orthic	Pallic	Rounded stony	silty	Well
Grasmere	618	Gley	Recent	Acidic	Stoneless	clayey over silty	Poor
Greenfield	23	Recent	Fluvial	Weathered	Rounded stony	silty	Well
Grove Burn	220	Brown	Acid	Typic	Stoneless	silty	Moderately well
Haycocks	204	Brown	Orthic	Calcareous	Lithic	clayey	Well
Hazlett	110	Brown	Orthic	Mottled	Moderately deep /rock	silty over clayey	Imperfect
Hedgehope	508	Brown	Orthic	Typic	Stoneless	silty	Moderately well
Hokonui	4098	Pallic	Perch-gley	Argillic	Stoneless	clayey	Poor
Honeywood	702	Brown	Firm	Mottled-acidic	Rounded stony	clayey	Imperfect
Howe	800	Recent	Fluvial	Typic	Soils with stones	loamy	Moderately well
Invercargill	10250	Organic	Humic	Acid	Deep (Sd)	peat or litter	Very poor
Isla Bank	3209	Brown	Orthic	Typic	Stoneless	silty	Moderately well
Jacobs	403	Gley	Recent	Saline	Stoneless	silty over sandy	Poor
Jacobstown	27043	Gley	Orthic	Acidic	Stoneless	silty	Poor
Josephville	1463	Brown	Orthic	Pallic	Soils with stones	silty	Well
Kaihiku	11550	Melanic	Orthic	Argillic	Angular-stony	loamy	Well
Kaiwera	4502	Brown	Allophanic	Acidic	Angular-stony	clayey	Well
Kakapo	111	Gley	Orthic	Typic	Soils with stones	silty over skeletal	Poor
Kapuka	3582	Podzol	Pan	Firm	Soils with stones	silty over skeletal	Imperfect
Kauana	2195	Melanic	Rendzic	Typic	Lithic	silty	Well
Kaweku	4402	Brown	Orthic	Acidic	Rounded stony	silty	Moderately well
Kaweku scarp	900	Brown	Orthic	Acidic	Rounded stony	silty	Moderately well
Kuriwao	4070	Brown	Firm	Acidic	Angular-stony	clayey	Well
Landslip	127	Brown	Sandy	Acidic			Poor
Lillburn	18	Brown	Orthic	Acidic	Moderately deep /rock	silty over clayey	Moderately well
Lintley	2739	Brown	Orthic	Pallic	Angular-stony	silty	Well
Lithosol	60	Raw	Rocky		Fragmental		Well
Longridge	2443	Gley	Orthic	Typic	Angular-stony	silty	Poor
Lumsden	2779	Gley	Orthic	Typic	Rounded stony	silty	Poor
Lyoncross	3264	Brown	Orthic	Typic	Stoneless	silty	Moderately well
Mahara	157	Recent	Fluvial	Acidic-weathered	Fragmental		Moderately well
Makarewa	38622	Gley	Orthic	Typic	Stoneless	clayey	Poor
Malakoff	1158	Melanic	Mafic	Typic	Soils with stones	silty over clayey	Well
Manapōuri	1296	Gley	Recent	Typic	Stoneless	silty	Poor
Mandeville	2271	Melanic	Mafic	Typic	Lithic	clayey	Well
Mangapiri	4875	Gley	Orthic	Argillic	Stoneless	clayey	Poor
Mararoa	1127	Brown	Orthic	Typic	Soils with stones	silty over skeletal	Well

Soil Name	Area (hectares)	NZSC Order	NZSC Group	NZSC Subgroup	Profile Material	Particle Size	Drainage class
Mataura	10127	Recent	Fluvial	Typic	Soils with stones	silty over skeletal	Well
McGaw	520	Brown	Firm	Mottled	Stoneless	clayey over silty	Imperfect
McIvor	954	Melanic	Rendzic	Typic	Angular-stony	clayey	Well
McKerchar	100	Gley	Orthic	Typic	Rounded stony	clayey	Poor
McLeish	660	Gley	Orthic	Typic	Rounded stony	clayey	Poor
McNab	955	Brown	Acid	Typic	Moderately deep /rock	silty	Moderately well
Merrivale	1894	Brown	Firm	Typic	Stoneless	silty	Moderately well
Mokotua	17699	Brown	Orthic	Mottled-acidic	Stoneless	silty	Imperfect
Monowai	9539	Brown	Allophanic	Cemented	Rounded stony	loamy	Well
Mossburn	5734	Pallic	Perch-gley	Fragic	Stoneless	silty	Poor
Mount Mistake	1281	Brown	Orthic	Acidic	Moderately deep /rock	silty	Well
Nithdale	887	Brown	Orthic	Acidic	Stoneless	silty	Well
Nokomai	895	Pallic	Immature	Typic	Stoneless	silty	Moderately well
Northope	1563	Pallic	Immature	Mottled-pedal	Stoneless	silty	Imperfect
Ohai	5370	Pallic	Perch-gley	Argillic	Stoneless	clayey	Poor
Omaui	597	Gley	Orthic	Ironstone	Soils with stones	silty over sandy	Poor
Orawia	3163	Brown	Orthic	Typic	Stoneless	silty over clayey	Moderately well
Orepuki	2211	Brown	Orthic	Acidic	Moderately deep /rock	silty	Well
Ōreti	12841	Brown	Firm	Cemented	Rounded stony	clayey	Well
Ōreti scarp	900	Brown	Orthic	Acidic	Rounded stony	Silty	Moderately well
Otahu	304	Pallic	Perch-gley	Fragic	Stoneless	silty	Poor
Otahuti	1026	Brown	Orthic	Typic	Soils with stones	clayey over skeletal	Well
Otaitai	1975	Gley	Sandy	Typic	Stoneless	sandy	Poor
Otakau	966	Gley	Recent	Acidic	Stoneless	silty over sandy	Poor
Otama	1736	Pallic	Laminar	Typic	Stoneless	silty	Moderately well
Otanomomo	14262	Organic	Mesic	Mellow	Shallow (Sh)	peat	Very poor
Otaraia	15089	Brown	Firm	Acidic	Stoneless	silty	Well
Otatara	3134	Brown	Sandy	Typic	Stoneless	sandy	Well
Otepuni	138	Gley	Recent	Typic	Rounded stony	silty	Poor
Oteramika	1717	Brown	Firm	Acidic	Rounded stony	silty	Imperfect
Otikerama	1058	Recent	Fluvial	Typic	Stoneless	silty	Moderately well
Oughton	336	Brown	Orthic	Acidic	Stoneless	clayey	Moderately well
Papatotara	2262	Brown	Orthic	Immature	Stoneless	silty	Well
Paretai	178	Gley	Recent	Typic	Stoneless	silty over peaty	Poor
Pebbly Hills	1135	Brown	Firm	Acidic-allophanic	Rounded stony	silty	Well
Pomahaka	133	Recent	Fluvial	Mottled	Stoneless	silty	Imperfect
Popotunoa		Pallic	Immature	Pedal	Stoneless	silty	Moderately well
Pourakino	4254	Brown	Firm	Typic	Stoneless	silty	Moderately well
Princhester	1317	Brown	Allophanic	Pedal	Soils with stones	clayey over silty	Well
Pukeawa	46	Recent	Rocky	Typic	Lithic	silty	Well
Pukekoma	468	Brown	Acid	Typic	Angular-stony	silty	Well
Pukemutu	47747	Pallic	Perch-gley	Argillic-fragic	Stoneless	silty over clayey	Poor
Pukerangi	163	Pallic	Argillic	Typic	Soils with stones	silty over skeletal	Moderately well

Soil Name	Area (hectares)	NZSC Order	NZSC Group	NZSC Subgroup	Profile Material	Particle Size	Drainage class
Pukerau	2343	Allophanic	Orthic	Typic	Lithic	clayey	Well
Pyramid	73	Pallic	Argillic	Typic	Soils with stones	silty over clayey	Moderately well
Redcliff	2023	Melanic	Orthic	Argillic	Rounded stony	clayey	Well
Riversdale	20171	Recent	Fluvial	Typic	Rounded stony	silty	Well
Riverton	2877	Recent	Sandy	Typic	Stoneless	sandy	Well
Rosemarkie	43	Brown	Allophanic	Acidic	Stoneless	silty	Well
Scrubby Hill	769	Brown	Acid	Mottled-placic	Stoneless	silty	Imperfect
Sobig	3486	Pallic	Perch-gley	Argillic	Soils with stones	clayey over silty	Poor
Stirling	15	Organic	Mesic	Acidic	Deep	peat	Poor
Stonycreek	716	Melanic	Perch-gley	Argillic	Angular-stony	silty	Imperfect
Tailings	3488	Anthropic	Fill	Stony-tailings	Rounded stony		Moderately well
Taringatura	2200	Brown	Orthic	Acidic	Angular-stony	silty	Well
Te Anau	10125	Brown	Allophanic	Firm	Rounded stony	silty	Moderately well
Te Waewae	7367	Brown	Firm	Typic	Stoneless	silty	Moderately well
Tisbury	4067	Gley	Orthic	Acidic	Stoneless	silty	Poor
Titipua	4498	Gley	Orthic	Peaty	Stoneless	clayey over silty	Poor
Tiwai	2372	Podzol	Pan	Humose	Soils with stones	silty over skeletal	Imperfect
Tokanui	16026	Brown	Firm	Typic	Stoneless	silty	Well
Tomoporakau	1408	Pallic	Perch-gley	Typic	Stoneless	silty	Poor
Trail		Podzol	Pan	Placic			Moderately well
Tuapeka	43	Brown	Orthic	Acidic	Angular-stony	silty	Moderately well
Tuatapere	6516	Melanic	Mafic	Typic	Stoneless	silty	Well
Tuturau	11454	Brown	Orthic	Pallic	Stoneless	silty	Moderately well
Tyneholm	1000	Brown	Orthic	Typic	Lithic	silty	Well
Upukerora	10179	Recent	Fluvial	Typic	Fragmental	silty	Well
Venlaw	284	Allophanic	Orthic	Acidic	Angular-stony	clayey	Well
Waianiwa	1495	Brown	Firm	Mottled-acidic	Stoneless	silty over clayey	Imperfect
Waiau	7205	Recent	Fluvial	Typic	Rounded stony	silty	Well
Waihoaka	3491	Podzol	Pan	Humose	Stoneless	Silty	Well
Waikaka	5862	Brown	Firm	Pallic	Stoneless	silty	Moderately well
Waikiwi	28083	Brown	Firm	Typic	Stoneless	silty	Moderately well
Waikoikoi	62721	Pallic	Perch-gley	Fragic	Stoneless	silty	Well
Waimahaka	1511	Brown	Firm	Typic	Stoneless	silty	Poor
Waimatuku	7630	Brown	Firm	Typic	Stoneless	silty	Moderately well
Waipapa	777	Brown	Allophanic	Mottled-placic	Stoneless	silty	Moderately well
Wairaki	1838	Brown	Orthic	Typic	Rounded stony	silty	Imperfect
Waituna	740	Brown	Allophanic	Typic	Rounded stony	silty	Moderately well
Waituna	182	Recent	Fluvial	Typic	Fragmental	silty	Well
Warepa	2625	Pallic	Fragic	Mottled	Stoneless	silty	Imperfect
Wendon	6441	Brown	Orthic	Acidic	Lithic	silty	Well
Wendonside	1314	Brown	Firm	Cemented	Rounded stony	silty	Moderately well
Weydon	80	Gley	Orthic	Acidic	Stoneless	silty	Poor
Winton	1913	Pallic	Immature	Pedal	Soils with stones	silty over skeletal	Moderately well
Woodlands	25040	Brown	Firm	Mottled	Stoneless	silty	Imperfect

Soil Name	Area (hectares)	NZSC Order	NZSC Group	NZSC Subgroup	Profile Material	Particle Size	Drainage class
Woodlaw	620	Brown	Orthic	Typic	Moderately deep /rock	clayey	Moderately well
Wyndham	3875	Brown	Firm	Mottled-pallic	Stoneless	silty	Imperfect

Appendix 2: B+LNZ Sheep and Beef Farm Survey

B+LNZ's Economic Service has conducted its Sheep and Beef Farm Survey since the late 1950s. It surveys a sample of around 530 commercial sheep and beef farms each year (or about 4.3% of the population of commercial sheep and beef farms). The sample is developed in conjunction with official New Zealand statistics collated through the Agriculture Production Statistics by Statistics New Zealand. The sample is stratified by region and Farm Class and designed to be statistically representative of the population of commercial sheep and beef farms in New Zealand.

The B+LNZ Sheep and Beef Farm Survey has eight Farm Classes – four extensive and intensive classes, with "intensity" defined by a combination of land type and appropriate farm management (the Farm Classes are described in Section **Error! Reference source not found.** – **Error! Reference source not found.**).

B+LNZ's staff collect and analyse data about the whole farm business, including production, inputs, e.g., fertiliser, sales and purchases of all species and classes of livestock (including transfer in and out for grazing), revenue and expenditure, balance sheet and flow of funds. The Survey collects actual data, not intentions, and does not "model", or define "typical", farms.

B+LNZ's Economic Service Managers (ESMs) have contact with Survey farmers at a number of times each year, including:

- Conducting a livestock number survey;
- Conducting a survey of the number of lambs tailed; and
- Visiting each farm each year to collect key information from the farmer.

In addition, ESMs obtain and analyse a full set of accounts for each farm business. They characterise each farm by up to 2000 measures and subject each record to over 700 compound validation checks to ensure integrity of the data.

For analysis at the Farm Class, production region and New Zealand level, the individual farm data are aggregated using a series of weights that enable the sample information to reflect the population of commercial sheep and beef farms with acceptable statistical accuracy.

The B+LNZ Sheep and Beef Farm Survey is primarily a means to provide key trends at the farm, production region and New Zealand level; and a robust base of data to:

- Forecast livestock numbers (nine months ahead of New Zealand's official estimates);
- Forecast lambing and calving performance (18 months ahead of New Zealand's official estimates);
- Forecast meat (and wool) production;
- Forecast revenue, expenditure, balance sheet and thus profitability of the sector;
- Provide benchmarking analysis;
- Conduct cost-benefit work evaluated to the farm level; and
- Answer policy questions.

The B+LNZ Sheep and Beef Farm Survey framework (i.e. sample) served as the base for **The Southland Economic Project**.

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